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Volume VIII

Edited by

CARLETON REA and J. RAMSBOTTOM

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British Museum (Nat. Hist.), Cromwell Road, London, S.W. 7.

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and
J. Ramsbottom, M.A., F.L.S., O.B.E.

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J. Ramsbottom, M.A., F.L.S.

The President and Secretary of the Society *ex Officio*.

THE WORCESTER FORAY.

September 19th to September 24th, 1921.

The twenty-fifth annual meeting and autumn foray took place at Worcester, at the invitation of the Worcestershire Naturalists' Club, from September 19th to 24th, 1921.

A few members of the party assembled during the previous week-end, and on the Sunday Mr Carleton Rea arranged a short expedition in the Malvern district. The party travelled to Malvern Link by motor-bus, and then walked down the Cowleigh Road to Cowleigh Wood. Subsequently a visit was made to Croft Wood, which is just over the border in Herefordshire. The return journey was made through Great Malvern. This expedition provided quite a number of species with which to start the week's work.

As usual the majority of the members assembled on the Monday evening and were welcomed on their visit to Worcestershire by the Vice-President (Mr F. T. Spackman, F.G.S.) and members of the Worcestershire Naturalists' Club at a conversazione in the Art Gallery at the Victoria Institute, Worcester. In the morning of Tuesday, September 20th, a council meeting was held, and this was followed in the evening of the same day by the annual general meeting.

Mr F. T. Brooks, M.A., was elected President for 1922, and Dr E. J. Butler was chosen to fill the vacancy thus caused in the Council.

In place of the two members retiring according to rule, Professor O. V. Darbishire and Mr C. H. Grinling were elected members of the Council. The other officers were re-elected.

It was decided to hold the autumn foray in 1922 at Keswick, and to arrange the period to include a week-end, if possible that of September 16th–17th.

Mr W. N. Cheesman was appointed delegate of the Society to the British Association meeting at Hull.

The whole of Tuesday was taken up by an expedition to Wyre Forest. The party took train to Cleobury Mortimer, and after a short walk along the road entered Weston Firs and Weston Plantation. After lunch Coachroad Coppice and the open ground adjoining Furnace Mill were visited, and then the path along Dowles Brook was followed as far as Wyre Forest Station, whence the return journey was made. Owing to the exceptionally dry summer the forest was not as rich in fungi

as usual, and considerable hunting had to be done. Old charcoal heaps yielded a few charcoal-loving species, as *Polystictus perennis, Humaria carbonigena, Pyronema confluens,* and *Collybia ambusta.* Some stacks of birch logs near Dowles Brook were rich in micro-fungi. A noteworthy find here was *Hymenochaete tabacina,* which appears to be much more rare in this country than *H. rubiginosa* and *H. corrugata. Russula chloroides* was abundant, and *Nyctalis parasitica* was found everywhere on decaying *R. nigricans.* Mr W. B. Allen brought a number of rare and interesting species from Horderley and Benthall, Shropshire.

On Wednesday Ockeridge Wood and Monk Wood were visited. The former proved most productive, very few additions to the list being made in Monk Wood which was more dry. Some fine specimens of *Pholiota squarrosa* were secured at the base of an *Abies,* which is an unusual habitat for this species. The best finds of the day were *Hygrophorus Wynniae* and *Otidea leporina,* the latter gathered by Miss M. Brett. In the evening Mr Carleton Rea delivered his Presidential Address.

On Thursday a visit was paid to Shrawley Wood and was remarkable for the large number of specimens of the somewhat rare *Strobilomyces strobilaceus.* A characteristic tree here was the small-leaved Lime (*Tilia cordata*), and a number of resupinates, including *Tulasnella incarnata,* were recorded on this host. Some fine tufts of *Polyporus intybaceus* were found growing at the roots of Sweet Chestnut (*Castanea vesca*). This day's foray proved the most interesting of all, this wood being damper than others visited. *Clitocybe cinerascens* (Bull.) Quél., *Craterellus cornucopioides, Cortinarius triumphans, C. cyanopus, Lactarius lilacinus, Polyporus rutilans, P. mollis* and *Corticium atrovirens* were among the more noteworthy finds. The owner (Mrs J. H. Allan) very kindly entertained the Council to a welcome cup of tea and the President reported that on a preliminary visit to this wood in company with their foray secretary, Mr A. A. Pearson, he had found *Arachnopeziza nivea* Lort, a discomycete new to the British fungus flora.

In the evening Professor A. H. R. Buller gave a short paper, illustrated by lantern-slides, on "Snails in relation to Fungi," and Dr Butler initiated a discussion on "The Amateur in relation to Mycology."

An expedition to the Trench Woods was made on Friday. These were very dry, and very few of the larger fungi were found, but notwithstanding this Miss C. A. Cooper detected specimens of *Astrosporina duriuscula; Mycena dilatata* and *Androsaceus epiphylloides,* and some interesting micro-forms also occurred. In one spot a large patch of *Corticium fasti-*

diosum was found on the bare clayey soil. *Sebacina incrustans* and *Thelephora anthocephala* occurred in similar situations. In a grassy drive leaves of *Spiraea Ulmaria* yielded numerous specimens of a small spider attacked by *Isaria arachnophila*. Of the larger forms the most outstanding find was a magnificent specimen of *Polyporus rufescens*, brought in by Mr S. P. Wiltshire.

In the evening Mr J. Ramsbottom gave a paper on "The origin of saprophytism in Phanerogams."

The meeting concluded with cordial votes of thanks to the Worcester Museum and Library Committee for the use of the Victoria Institute and Library, to the Education Committee for the use of the lecture theatre and to the various owners and tenants who had given permission for visits to their estates. Votes of thanks were also passed to the President, to the Foray Secretary, Mr Pearson, and to Miss Wakefield.

For assistance in compiling the following list of species found I am especially indebted to Mr Carleton Rea, Mr J. Ramsbottom and Dr J. S. Bayliss Elliott. The latter is responsible for many records of Discomycetes.

Wo. = Neighbourhood of Worcester. *W.* = Wyre Forest. *O.* = Ockeridge Wood and Monk Wood. *S.* = Shrawley Wood. *T.* = Trench Woods. *C.* = Cowleigh Wood. *Cr.* = Croft Wood.

HYMENOMYCETES.

Amanita phalloides (Vaill.) Fr. *W.S.*, mappa (Batsch) Fr. *W.S.*, muscaria (L.) Fr. *W.S.*, rubescens Fr. *S.*, nitida Fr. *S.*

Amanitopsis vaginata (Bull.) Roze *W.S.*, strangulata Fr. *C.*

Armillaria mellea (Vahl.) Fr.

Lepiota procera (Scop.) Fr. *W.*, rachodes (Vitt.) Fr. *S.*, gracilenta (Krombh.) Fr. *W.*, acutesquamosa (Weinm.) Fr., amianthina (Scop.) Fr. *O.*, Bucknallii B. and Br.

Tricholoma sejunctum (Sow.) Fr. *O.*, resplendens Fr. *C.*, spermaticum Fr. *S.*, flavobrunneum Fr. *O.*, rutilans (Schaeff.) Fr. *W.O.*, chrysites (Jungh.) Gill. *C.*, saponaceum Fr. *S.T.*, sulphureum (Bull.) Fr. *S.*, nudum (Bull.) Fr. *S.*, melaleucum (Pers.) Fr. *W.*, var. polioleucum Fr. *W.*

Clitocybe clavipes (Pers.) Fr. *W.*, phyllophila Fr. *W.*, aggregata (Schaeff.) Fr. *S.*, infundibuliformis (Schaeff.) Fr. *C.*, inversus (Scop.) Fr. *W.*, metachroa, Fr. *O.*, fragrans (Sow.) Fr. *S.*, cinerascens (Bull.) Quél. *S.*

Laccaria laccata (Scop.) B. and Br. *C.S.O.*, var. amethystina (Vaill.) B. and Br. *C.*

Collybia radicata (Relh.) Berk. *W.*, platyphylla Fr. *W.*, fusipes (Bull.) Berk. *C.S.*, distorta Fr. *O.*, butyracea (Bull.) Fr. *S.*, velutipes Fr. *W.O.*, dryophila (Bull.) Fr. *C.T.*, aquosa (Bull.) Fr. *C.*, ambusta Fr. *W.*

Mycena pura (Pers.) Fr. *S.*, rugosa Fr. *C.*, galericulata (Scop.) Fr. *O.T.*, polygramma (Bull.) Fr. *C.O.T.*, inclinata Fr. *O.*, amicta Fr. *W.*, sanguinolenta (A. and S.) Fr. *O.*, galopus (Pers.) Fr. *W.S.*, var. nigra Fl. Dan. *W.S.T.*, epipterygia (Scop.) Fr. *O.*, dilatata Fr. *T.*, tenerrima Berk. *O.*

Omphalia fibula (Bull.) Fr. *C.*, var. Swartzii Fr. *C.*, integrella (Pers.) Fr. *W.*

Pleurotus ulmarius (Bull.) Fr., subpalmatus Fr. *Wo.*, acerosus Fr. *W.*, applicatus (Batsch) Berk. *T.*

Hygrophorus eburneus (Bull.) Fr. *W.*, conicus Fr. *S.*, Wynniae B. and Br. *O.*

Lactarius scrobiculatus (Scop.) Fr., torminosus (Schaeff.) Fr. *W.*, turpis (Weinm.) Fr. *S.*, pubescens Fr. *C.*, insulsus Fr. *C.*, blennius Fr. *S.*, uvidus Fr. *T.*, pyrogalus (Bull.) Fr. *W.O.T.*, chrysorheus Fr. *W.S.*, vellereus Fr. *O.T.*, deliciosus (L.) Fr. *W.*, quietus Fr., rufus (Scop.) Fr. *O.*, glyciosmus

Fr. *S.*, fuliginosus Fr. *S.T.*, lilacinus (Lasch) Fr. *S.*, serifluus (DC.) Fr. *S.*, mitissimus Fr. *O.S.*, subdulcis (Pers.) Fr. *Cr.W.S.*

Russula nigricans (Bull.) Fr., adusta (Pers.) Fr. *S.T.*, chloroides (Krombh.) Bres. *C.W.S.T.*, furcata (Pers.) Fr. *C.*, caerulea (Pers.) Fr. *W.O.*, atropurpurea (Krombh.) Maire *W.O.S.*, rubra (Krombh.) Bres. *O.*, drimeia Cooke, *O.*, virescens (Schaeff.) Fr. *O.*, lepida Fr. *C.S.T.*, xerampelina (Schaeff.) Fr. *Cr.W.O.S.*, vesca Fr. *O.*, cyanoxantha (Schaeff.) Fr. *C.W.*, consobrina Fr. *S.*, var. sororia Fr. *O.*, foetens (Pers.) Fr. *Cr.O.W.S.T.*, emetica (Schaeff.) Fr. *W.*, ochroleuca (Pers.) Fr. *C.W.S.T.*, fragilis Fr. *C.S.T.*, nitida (Pers.) Fr. *S.*, punctata (Gill.) Maire *C.T.*, armeniaca Cke. *S.*, lutea (Huds.) Fr. *S.*

Cantharellus cibarius Fr. *W.T.*, aurantiacus (Wulf.) Fr. *C.W.*

Nyctalis parasitica (Bull.) Fr., asterophora Fr. *S.*

Marasmius oreades (Bolt.) Fr. *C.*, ramealis (Bull.) Fr. *O.T.*, rotula (Scop.) Fr. *W.*

Androsaceus epiphylloides Rea *T.*

Lentinus cochleatus (Pers.) Fr. *W.Wo.*

Panus stypticus (Bull.) Fr. *W.*

Schizophyllum commune Fr. *S.*

Pluteus cervinus (Schaeff.) Fr. *W.O.S.*, salicinus (Pers.) Fr. *S.*, nanus (Pers.) Fr. *O.T.*

Clitopilus prunulus (Scop.) Fr. *W.S.*

Claudopus variabilis (Pers.) W. G. Sm. *O.*

Pholiota aegerita (Porta) Fr. *Wo.*, squarrosa (Mull.) Fr. *O.* (at base of *Abies*), marginata (Batsch) Fr. *O.S.*, mutabilis (Schaeff.) Fr. *W.S.*

Inocybe cincinnata Fr. *T.*, pyriodora (Pers.) Fr. *S.*, rimosa (Bull.) Fr. *S.*, duriuscula Rea *T.*, asterospora Quél., geophylla (Sow.) Fr. *Cr.W.T.*, var. violacea Pat. *S.*

Hebeloma fastibile Fr. *W.O.*, glutinosum (Lindg.) Fr. *S.*, mesophaeum Fr. *W.O.*, crustuliniforme (Bull.) Fr. *C.*

Flammula carbonaria Fr. *W.*, ochrochlora Fr. *O.*, sapinea Fr. *O.S.*

Naucoria melinoides (Bull.) Fr. *W.O.*, escharoides Fr. *O.S.*

Pluteolus aleuriatus Fr. *C.O.*

Galera hypnorum (Schrank) Fr. *W.*

Tubaria furfuracea (Pers.) W. G. Sm. *W.*, inquilina Fr. *C.*

Crepidotus mollis (Schaeff.) Fr. *O.*

Cortinarius (Phlegmacium) triumphans Fr. *S.*, varius (Schaeff.) Fr. *C.*, cyanopus Fr. *S.*, (Myxacium) elatior (Pers.) Fr. *S.*, (Dermocybe) tabularis (Bull.) Fr. *S.*, lepidopus Cke. *S.*, cotoneus Fr., (Telamonia) macropus Fr. *S.*, torvus Fr. *S.*, hinnuleus (Sow.) Fr. *C.W.*, hemitrichus (Pers.) Fr. *S.*, (Hydrocybe) leucopus (Bull.) Fr. *S.*, decipiens (Pers.) Fr. *S*

Paxillus involutus (Batsch) Fr. *C.W.*

Psaliota purpurascens Cke. *S.*, campestris (Linn.) Fr. *C.*, silvatica (Schaeff.) Fr. *S.*, haemorrhoidarius Kalchbr. *W.*

Stropharia aeruginosa (Curt.) Fr. *O.S.*, semiglobata (Batsch) Fr. *Cr.*

Hypholoma sublateritium (Schaeff.) Fr. *O.T.*, fasciculare (Huds.) Fr., epixanthum (Paul.) Fr. *C.W.*, pyrotrichum (Holmsk.) Fr. *W.*, velutinum (Pers.) Fr. *W.O.*, appendiculatum (Bull.) Fr. *W.O.*, hydrophilum (Bull.) Fr. *W.O.S.*

Psathyra corrugis (Pers.) Fr. *O.S.T.*

Bolbitius titubans (Bull.) Fr. *C.*

Coprinus atramentarius (Bull.) Fr. *W.O.*, sterquilinus Fr. *S.*, cinereus (Schaeff.) Fr. *Cr.O.*, niveus (Pers.) Fr. *Cr.*, micaceus (Bull.) Fr. *W.S.*, domesticus (Pers.) Fr. *W.O.*, plicatilis (Curt.) Fr. *W.O.*

Panaeolus sphinctrinus Fr. *C.W.*, campanulatus (Linn.) Fr. *C.*, papilionaceus (Bull.) Fr. *S.*

Anellaria separata (Linn.) Karst. *C.*

Psathyrella gracilis (Pers.) Fr. *C.*, disseminata (Pers.) Fr. *O.S.*

Gomphidius viscidus (Linn.) Fr. *W.*, maculatus (Scop.) Fr. *O.*, gracilis Berk. *O.*

Boletus luteus (Linn.) Fr. *W.*, elegans (Schum.) Fr. *W.O.*, granulatus (Linn.) Fr. *W.*, badius Fr. *W.S.*, piperatus (Bull.) Fr. *W.*, chrysenteron (Bull.) Fr. *W.S.*, versicolor Rost. *S.*, edulis (Bull.) Fr. *C.*, laricinus Berk. *Cr.O.*,

versipellis Fr. *C.W.*, scaber (Bull.) Fr. *W.S.T.*, felleus (Bull.) Fr. *S.*, appendiculatus (Schaeff.) Fr. *S.*
Strobilomyces strobilaceus (Scop.) Berk. *S.*
Fistulina hepatica (Huds.) Fr. *W.O.*
Polyporus squamosus (Huds.) Fr. *S.*, rufescens (Pers.) Fr. *T.*, Schweinitzii Fr. *T.*, varius Fr. *O.*, elegans (Bull.) Fr., var. nummularius Fr. *T.*, intybaceus Fr. *S.* (on *Castanea vesca*), giganteus (Pers.) Fr. *S.*, dryadeus Fr. *Wo.S.*, hispidus Fr. *Wo.*, mollis Fr. *S.*, rutilans (Pers.) Fr. *S.*, betulinus (Bull.) Fr., adustus (Willd.) Fr. *W.*, fragilis Fr. *W.S.*
Fomes connatus Fr. *W.*, annosus Fr. *W.O.S.*, igniarius Fr. *W.*, pomaceus (Pers.) Fr. *Wo.*, ferruginosus (Fr.) Mass. *W.*
Ganoderma lucidum (Leyss.) Karst. *T.*
Polystictus perennis (Linn.) Fr. *W.*, versicolor (Linn.) Fr. *C.W.*, radiatus (Sw. Fr. *W.*, hirsutus (Schrad.) Fr. *O.S.*, Wynniae (Berk.) Cooke, *O.*
Poria eupora Karst. *T.*, sanguinolenta Fr. *O.*
Daedalea quercina (Linn.) Fr. *C.O.*, confragosa (Bolt.) Fr. *O.*
Merulius tremellosus (Schrad.) Fr. *W.S.*, corium Fr. *S.*
Hydnum repandum (Linn.) Fr. *W.O.T.*, var. rufescens (Pers.) Fr. *S.*, udum Fr. *W.S.T.*
Irpex obliquus (Schrad.) Fr. *W.O.T.*
Phlebia merismoides Fr. *T.*, radiata (Sow.) Fr. *W.O.*
Odontia fimbriata (Pers.) Fr. *W.O.*, farinacea (Pers.) Quél. *O.T.*
Grandinia granulosa Fr. *T.*
Craterellus cornucopioides (Linn.) Fr. *S.*
Thelephora anthocephala Fr. *Cr.O.T.*
Stereum hirsutum (Willd.) Fr. *W.*, purpureum (Pers.) Fr. *C.Wo.*, rugosum (Pers.) Fr. *Cr.T.*, sanguinolentum (A. and S.) Fr. *W.*, spadiceum Fr. *T.*
Hymenochaete tabacina (Pers.) Lév. *W.*
Corticium arachnoideum B. and Br. *S.T.*, botryosum Bres. *W.T.*, confine Bourd. and Galz. *T.*, fastidiosum (Pers.) Bres. *T.*, echinosporum Ell. *W.*, caeruleum (Schrad.) Fr. *O.*, atrovirens Fr. *S.*, Pearsonii Bourd., porosum B. and Br. *W.T.*, polygonium (Pers.) Fr. *S.* (on *Tilia*).
Peniophora Aegerita v. H. and Lit. *O.*, glebulosa Bres. *O.T.*, subalutacea (Karst.) v. H. and L., longispora (Pat.) v. H. and L. *T.*, sanguinea (Fr.) Bres. *O.T.*, cremea Bres. *W.*, setigera (Fr.) Bres. *T.*, aurantiaca Bres. *O.S.T.*, cinerea (Fr.) Cke. *O.S.T.*, quercina (Pers.) Cke. *Cr.W.T.*, hydnoides C. and M. *W.O.T.*
Hypochnus fuscus (Pers.) Karst. *W.T.*, ferrugineus (Pers.) Fr. *T.*
Coniophora puteana (Schum.) Fr. *W.*
Solenia anomala (Pers.) Fr.
Clavaria cinerea (Bull.) Fr. *W.O.S.*, cristata (Holmsk.) Fr. *W.O.T.*, rugosa (Bull.) Fr. *W.*, inaequalis (Müll.) Fr. *C.S.*
Pistillaria puberula Berk. *O.*
Hirneola Auricula-Judae (Linn.) Fr. *O.S.*
Tremella mesenterica (Retz.) Fr. *T.*
Exidia glandulosa (Bull.) Fr. *S.*
Sebacina incrustans Tul. *Cr.T.*
Dacryomyces deliquescens (Bull.) Duby, *W.S.T.*
Femsjonia luteo-alba Fr. *W.*
Calocera cornea (Batsch) Fr. *W.O.S.*, stricta Fr. *W.*, viscosa (Pers.) Fr. *W.*
Tulasnella incarnata Juel *S.T.*
Phallus impudicus (Linn.) Pers. *S.*
Mutinus caninus (Huds.) Fr. *O.*
Cyathus striatus Hoffm. *O.*
Crucibulum vulgare Tul. *S.*
Lycoperdon perlatum Pers. *W.S.*, depressum Bon. *S.*, pyriforme (Schaeff.) Pers. *W.*
Scleroderma verrucosum (Bull.) Pers. *O.W.*

UREDINEAE.

Puccinia Violae (Schum.) DC. *O.*, pulverulenta Grev. *W.*, obtegens (Link) Tul. *C.Wo.*, Hieracii (Schum.) Mart. on *Hieracium boreale*, *T.*, Glechomatis DC.

O., Menthae Pers. *T.*, Caricis (Schum.) Rebent. on *Carex pendula*, *O.*, obscura Schroet. *C.O.S.*, Pruni-spinosae Pers. *S.*, secalina Grove *Wo.*
Triphragmium Ulmariae (Schum.) Link *T.*
Phragmidium violaceum (Schultz) Wint. *S.O.T.*
Kuehneola albida (Kuehn.) Magn. *W.O.T.*
Coleosporium Senecionis (Pers.) Fr. *S.*, Tussilaginis (Pers.) Kleb. *S.*
Pucciniastrum Circaeae (Schum.) Schroet. *O.T.*
Melampsora Euphorbiae Cast. *Wo.*
Melampsoridium betulinum (Pers.) Kleb. *W.*

USTILAGINEAE.

Sphacelotheca Hydropiperis (Schum.) de By. *O.*
Ustilago Scabiosae (Sow.) Wint.
Urocystis Violae (Sow.) Fisch. *S.*

PYRENOMYCETES.

Sphaerotheca pannosa (Wallr.) Lév. *Cr.*, Castagnei Lév. *S.T.*
Podosphaera oxyacantha (DC.) de By. *C.*
Uncinula Aceris (DC.) Sacc. *T.*
Phyllactinia suffulta (Rebent.) Sacc. *O.*
Erysiphe Cichoracearum DC. *S.*, graminis DC. *Wo.O.S.*, Galeopsidis DC. on *Lamium purpureum*, *S.*, tortilis (Wallr.) Fr. *T.*, Polygoni DC. *C.W.S.*
Nectria episphaeria (Tode) Fr. *W.*, coccinea (Pers.) Fr. *W.O.*, cinnabarina (Tode) Fr. *O.*
Hypomyces aurantius (Pers.) Tul. *O.*, rosellus (A. and S.) Tul. *S*
Hypocrea citrina Fr. *W.*, gelatinosa Fr. *O.*
Epichloe typhina (Pers.) Tul. *T.*
Cordyceps militaris (Linn.) Link *W.O.S.*
Leptospora ovina (Pers.) Fuck. *S.*
Lasiosphaeria hirsuta Ces. and de Not. *S.*
Rosellinia aquila (Fr.) de Not. *O.*
Sphaerella Fragariae Sacc. *S.*
Venturia inaequalis (Cooke) Aderh. on *Pyrus torminalis*, *T.*
Diaporthe leiphaemia Sacc. *T.*
Diatrypella quercina (Pers.) Nits. *O.S.*
Diatrype Stigma (Hoffm.) de Not. *W.*, disciformis (Hoffm.) Fr. *S.*, verrucaeformis Fr. *S.*
Hypoxylon multiforme Fr. *W.O.S.T.*, fuscum Fr. *W.*, coccineum Bull. *W.O.*, rubiginosum Fr. *W.*, serpens Fr. *T.*
Xylaria Hypoxylon (Linn.) Grev. *W.O.T.*
Phyllachora graminis (Pers.) Fuck. *O.*, Junci (Fr.) Fuck. *O.*

HYSTERIACEAE.

Rhopographus Pteridis (Sow.) Wint. *O.*
Hypoderma virgultorum DC. *S.*
Dichaena quercina Fr. *O.T.C.*

DISCOMYCETES.

Helvella crispa (Scop.) Fr. *W.*
Galactinia badia (Pers.) Boud. *T.*, succosa (Berk.) Sacc. *S.*
Peziza aurantia Pers. *W.*
Otidea leporina (Batsch) Fuck. *O.S.*
Aleuria sepiatra (Cooke) Boud. *W.*
Humaria carbonigena (Berk.) Sacc. *W.*
Lachnea hemisphaerica (Wigg.) Gill. *W.O.*
Cheilymenia rubra (Cke.) Boud. *W.*
Coprobia granulata (Bull.) Boud. *S.O.*
Ascobolus furfuraceus Pers. *S.W.*, vinosus Berk. *S.*
Cudoniella acicularis (Bull.) Schroet. *O.T.*
Calycella claroflava (Grev.) Boud. *S.*
Cornye sarcoides (Jacq.) Tul. *W.*

Orbilia xanthostigma Fr. *W.O.S.*
Hyalinia inflatula (Karst.) Boud. *W.S.T.*
Sclerotinia Curreyana (Berk.) Karst.—sclerotia only, *O.W.*
Phialea firma Pers. *W.C.*
Chlorosplenium aeruginosum (Oeder.) de Not. *O.T.*
Helotium herbarum (Pers.) Fr. *S.*, virgultorum (Wahl.) Karst. *O.T.*, cyathoideum (Bull.) Karst. *T.*
Dasyscypha virginea (Batsch) Fr. *W.T.*, ciliaris (Schrad.) Sacc. *W.S.T.*
Trichoscypha calycina (Schum.) Boud. *Cr.W.*
Hyaloscypha hyalina (Pers.) Boud. *W.*
Urceolella leuconica (Cooke) Boud. *O.*
Mollisia cinerea (Batsch) Karst. *W.O.S.T.*, Populi Bayliss Elliott *T.*
Pyronema confluens (Pers.) Tul. *W.*
Cenangium Prunastri (Pers.) Fr. *Wo.*
Propolis faginea (Schrad.) Karst. *W.*
Lecanidion proximum (B. and Br.) Sacc. *O.*
Stegia Ilicis Fr. *C.*
Rhytisma acerinum (Pers.) Fr. *W.T.*

PHYCOMYCETES.

Cystopus candidus (Pers.) de By. *S.*
Peronospora effusa (Grev.) Rabh. on *Chenopodium*, *Wo.S.*, parasitica (Pers.) Tul. *S.*, alta Fuck. *S.*
Bremia Lactucae Reg. on *Senecio vulgaris*, *Wo.*
Spinellus fusiger (Link) van Tiegh. *O.*
Syzygites megalocarpus Ehrb. *C.O.*
Thamnidium elegans Link *W.*

SPHAEROPSIDACEAE.

Phyllosticta Violae Desm. *S.*
Phoma conigena Karst. *O.*
Septoria Rubi Westend. *C.W.*, piricola Desm. *S.*, Fragariae Desm. *S.*

MELANCONIACEAE.

Gloeosporium Ribis (Lib.) Mont. and Desm. *S.*
Melanconium betulinum Schn. and Kunze *T.*

LEPTOSTROMACEAE.

Leptostroma juncacearum Sacc. *T.*

HYPHOMYCETES.

Oidium alphitoides Griff. and Maubl. *C.O.*
Monilia fructigena Schum. *Wo.*, cinerea Bon. *Wo.*
Rhinotrichum Thwaitesii B. and Br. *O.T.*
Sepedonium chrysospermum (Bull.) Fr. *C.W.O.S.*
Trichoderma viride (Pers.) Fr. *W.O.*
Botrytis cinerea Pers. *O.Wo.*
Ramularia calcea (Desm.) Ces. *C.*, lactea (Desm.) Sacc. *O.*, Knautiae (Mass.) Bub. *T.*, Primulae Thuem. *Cr.*
Ovularia obliqua (Cooke) Oud. *Cr.O.*
Sporotrichum sulfureum Grev. *T.*
Bispora monilioides Corda *O.*
Stachylidium cyclosporum Grove *W.*
Cercospora Mercurialis Passer. *O.*
Helicosporium viride Corda *S.*
Volutella ciliata Fr. *T.*
Isaria arachnophila Ditm. *S.T.*
Tilachlidium tomentosum (Schrad.) Lind. on *Trichia varia*, *S.*

LIST OF MYCETOZOA FOUND DURING THE WORCESTER FORAY.

From Sept. 19th to 23rd, 1921.

By G. Lister, F.L.S.

After the unusually dry summer, hopes for a good harvest of Mycetozoa were not high; some showers had fallen, however, in Worcestershire in August and September, with the result that every wood we visited produced something of interest. Altogether thirty-eight different species were observed—by no means the smallest number obtained on one of our autumn forays; but on the whole our gleanings were scanty, and several species that are usually abundant were represented by one or two gatherings only. *Diderma testaceum*, found in Shrawley Wood, is a new record for the county.

On Sept. 20th Wyre Forest with its extensive woods of oak, mixed with spruce, sweet-chestnut and poplar, and with undergrowth of bracken and bramble, gave us eighteen species; perhaps the largest development seen of any one species was of *Perichaena corticalis*, quantities of which were found on a pile of small wood on moist ground. Sept. 21st we visited Ockeridge and Monk Woods, consisting of oak, with some spruce, alder and yew, with undergrowth of hazel and bracken; a small plantation of larch arose from a bed of bramble too dense to afford good hunting ground. Large growths of *Cribraria argillacea* were seen on old yew logs, and several colonies of *Stemonitis hyperopta* were obtained on decaying oak, horse-chestnut and other wood; the latter species is distinguished in the field by its reddish lilac tint from the browner sporangia of *Comatricha typhoides*, of which it has until recently been considered a variety. Along a path running through Monk Wood, *Stemonitis fusca* was found maturing on patches of moist clay and dead leaves; the plasmodium had evidently been feeding on a layer of branches laid down as a foundation to the path, and had crept up through the clay to form sporangia. On Sept. 22nd we drove to Shrawley Wood, where groves of oak and lime surround two long ponds and marshy ground connecting them. On dead leaves beneath Rhododendrons, *Physarum sinuosum*, *Craterium leucocephalum*, *Leocarpus fragilis* and *Diachaea leucopoda* were found; the latter also occurred on moist herbage near the ponds; *Diderma testaceum* was gathered on dead bracken.

Physarum nutans in perfect condition was in great profusion almost everywhere on dead wood. Sept. 23rd Trench Woods, consisting of hazel, some ash, alder and a few scattered oaks, proved to be dry. Among the thirteen species of Mycetozoa obtained were our only gatherings of *Didymium squamulosum*.

The following is a list of the species recorded, with their distribution in the woods visited.

W. = Wyre Forest. *O.* = Ockeridge and Monk Woods. *S.* = Shrawley Wood. *T.* = Trench Woods.

Ceratiomyxa fruticulosa (Müller) Macbr. *W.O.S.T.*
Badhamia utricularis (Bull.) Berk. *W.O.S.T.*; seen in plasmodium only.
Physarum nutans Pers. *W.O.S.T.*
,, ,, subsp. *leucophaeum* *W.O.S.T.*
P. viride (Bull.) Pers. *O.*
P. cinereum (Batsch) Pers. *S.*
P. sinuosum (Bull.) Weinm. *S.T.*
Fuligo septica (L.) Gmel. *W.*
Craterium leucocephalum (Pers.) Ditm. *S.T.*
Leocarpus fragilis (Dicks.) Rost. *W.S.*
Diderma testaceum Pers. *S.*
Diachaea leucopoda (Bull.) Rost. *S.*
Didymium difforme (Pers.) Duby. *O.*
D. clavus (Alb. and Schw.) Rabenh. *O.*
D. nigripes Fries. S. and var. xanthopus (Fries) List. *O.*
D. squamulosum Fr. *T.*
Stemonitis fusca Roth. *W.O.S.T.*
S. herbatica Peck *O.*
S. ferruginea Ehrenb. *S.*
S. hyperopta Meyl. *O.S.*
Comatricha typhoides (Bull.) Rost. *W.O.*
C. nigra (Pers.) Schroet. *W.O.S.T.*
Cribraria argillacea Pers. *W.O.*
Tubifera ferruginosa (Batsch) Gmel. *W.*
Reticularia Lycoperdon Bull. *O.*
Lycogala epidendrum (L.) Fries *W.O.S.*
Trichia affinis de Bary. *W.O.S.T.*
T. scabra Rost. *S.*
T. persimilis Karst. *O.S.*
T. varia Pers. *O.*
T. decipiens (Pers.) Macbr. *W.O.S.*
T. Botrytis Pers. *O.*
Arcyria cinerea (Bull.) Pers. *O.S.*
A. pomiformis (Leers) Rost. *W.O.S.*
A. incarnata Pers. *W.O.S.T.*
A. denudata (L.) Wettst. *W.O.S.T.*
A. nutans (Bull.) Grev. *W.O.S.T.*
Perichaena corticalis (Batsch) Rost. *W.*

It may be noted that *Diachaea subsessilis* Peck, first recorded for Worcestershire by Mr E. Brazier, who gathered it near Stourbridge in November 1920, was obtained about the same time in Wyre Forest by Dr W. T. Elliott; this specimen is without any lime deposits, and was so inconspicuous that it was unnoticed for some months after gathering.

LICHENS FOUND DURING THE WORCESTER FORAY.

By H. H. Knight, M.A.

The woods generally in the Midland Counties have a poor Lichen Flora, and this was the case with those visited during the Foray. Also the northern part of the County may perhaps suffer from the smoke of the industrial towns of the Birmingham district.

In Ockeridge and Shrawley Woods the most noticeable feature was the abundance of *Calicium hyperellum* and *Chaenotheca melanophaea*, both growing on oaks. Another of the Caliciaceae, *Cyphelium inquinans*, was plentiful on old gates outside Trench Woods. Graphidaceae were scarce in all the woods, and *Graphis elegans* was seen on only one tree. A few saxicole species were noticed on walls by houses, and two common species of *Verrucaria* were found on Lias stones outside Trench Woods. Specimens of *Umbilicaria pustulata* gathered on Malvern Hills the previous week were exhibited at the meeting.

W. = Wyre Forest. *O.* = Ockeridge and Monk Woods.
S. = Shrawley Wood. *T.* = Trench Woods.

Chaenotheca melanophaea Zwackh. *O.S.*
Calicium hyperellum Ach. *O.S.*
Cyphelium inquinans Trev. *T.*
Peltigera canina Willd. *S.T.*
Parmelia physodes Ach. common.
P. caperata Ach. *S.*
P. saxatilis Ach. *W.*
P. sulcata Tayl. *O.S.*
P. dubia Schaer. *S.*
P. fuliginosa Nyl. var. laetevirens Nyl. common.
Evernia prunastri Ach. common.
Ramalina fastigiata Ach. *O.*
Usnea florida Web. var. hirta Ach. common.
Xanthoria parietina Th. Fr. on roofs etc.
X. lychnea Th. Fr. *T.*
Candelariella vitellina Müll.-Arg. *O.T.*
Lecanora subfusca Ach. var. allophana Ach. *O.S.*
L. campestris B. de Lesd. *O.T.*
L. galactina Ach. *O.*
L. varia Ach. common.
L. conizaea Nyl. *O.S.*
L. symmictera Nyl. *T.*
Pertusaria faginea Leight. common.
P. pertusa Dalla Torre and Sarnth. *O.S.*
P. leioplaca Schaer. *O.S.*
Phlyctis agelaea Koerb. *S.*
Cladonia fimbriata Fr. *W.S.* var. subcornuta Nyl. *W.*
C. pityrea Fr. *W.*
C. macilenta Hoffm. *S.*
C. bacillaris Nyl. *W.*
Lecidea ostreata Schaer. *W.O.*
L. coarctata Nyl. *W.*
L. uliginosa Ach. *S.*
L. parasema Ach. *S.T.*
Biatorina Griffithii Massal. *O.S.T.*
Buellia canescens de Not. *T.*
B. myriocarpa Mudd *T.*
Opegrapha herpetica Ach. *S.*
O. varia Pers. *T.*
O. vulgata Ach. *T.*
Graphis elegans Ach. *S.*
Verrucaria nigrescens Pers. *T.*
V. muralis Ach. *T.*
Arthopyrenia fallax Arn. *O.S.*
Porina carpinea A. Zahlbr. *S.*
Pyrenula nitida Ach. *S.*

PRESIDENTIAL ADDRESS.

By Carleton Rea, B.C.L., M.A., Hon. member British Mycological Society, etc.

A BRIEF REVIEW.

Twenty-five years ago the British Mycological Society was founded by a small band of enthusiastic mycologists at Selby, on the 19th of September, 1896. It was felt that the formation of such a club would fill a long-felt want. At that date there were comparatively few students of our fungi, mycologists were often unacquainted with each other, they had no place of meeting, and there was no journal exclusively devoted to this branch of botany. Hitherto these wants had been met to some extent by the fungus forays of the Woolhope Club, and the mycological papers published in *Grevillea*. These forays were inaugurated by Dr H. G. Bull in 1867 at Hereford and were continued annually with great success until his decease on the 31st of October, 1885, but afterwards languished and finally ceased in September, 1892. The last number of *Grevillea* was published in June, 1894, on the completion of the twenty-second volume. A circular letter was subsequently sent out in the following November addressed to the leading mycologists and Natural History Societies and about fifty members were enrolled in response thereto. These included Professor J. W. Carr, Messrs W. N. Cheesman, A. Clarke, Rev. F. K. Clarke, Messrs M. C. Cooke, Charles Crossland, Rev. Canon J. M. Du Port, Mr W. H. Edwards, Revs. W. L. Eyre, W. Fowler, H. P. FitzGerald, Messrs T. Gibbs, T. Hey, Professor T. Johnson, Dr P. Magnus, Dr Philip Mason, Mr George Massee, Dr E. McWeeney, Mr J. Needham, Dr H. G. Peacock, Mr Greenwood Pim, Dr C. B. Plowright, Professor M. C. Potter, Dr N. Rehm, Mr J. B. Robinson, Miss E. A. Rose, Mr J. Rose, Professor E. S. Salmon, Messrs M. B. Slater, H. T. Soppitt, Professor J. W. H. Trail, Dr Harold Wager, Professors H. Marshall Ward, F. E. Weiss and the Dublin and Woolhope Naturalists' Field Clubs. Some of these names still appear in our list of members whilst others have filled the presidential chair; and we all are greatly indebted to the Rev. W. L. Eyre for his kind assistance in bearing the cost of many plates for our *Transactions*. Mr George Massee in his presidential address to the society at its first meeting in September 1897 in Sherwood Forest, dealt with "Mycological progress during the last sixty years" and therein referred to the valuable work done by Berkeley and the brothers

Tulasne, and the important discoveries made by de Bary and Brefeld by means of pure cultures. Since that date we have had several other presidential addresses and papers devoted to the early workers with fungi and mycetozoa and their first appearance in our literature, and I thought that perhaps it would not be out of place if I directed your attention to-night to the progress that has been made in some branches of mycology since the foundation of this Society.

In 1900 Monsieur N. Patouillard published his brilliant "Essai taxonomique sur les familles et les genres des Hyménomycètes," which I ventured to outline at some length in my presidential address delivered to this Society at Drumnadrochit in September 1908. Patouillard in this work formulates a scheme of classification of the Basidiomycetae based on a study of the basidium and other microscopical characters. This classification is quite different from the old Friesian system of classification and brings together nearly related genera which were formerly kept far apart, such as Cantharellus and Craterellus, and Boletus and Paxillus. Whilst the old heterogeneous species included in the Thelephoraceae are now assigned to their appropriate places, such as *Thelephora sebacea* (Pers.) Fr. and *Corticium calceum* (Pers.) Fr. which are now transferred to *Sebacina incrustans* Tul. and *Sebacina calcea* (Pers.) Bres., I must say that I have been greatly disappointed to find that few British mycologists, with the exception of those who have devoted their attention to the study of our resupinate fungi, seem to appreciate the importance of this reclassification. They continue their studies as if nothing had happened to disturb the old Friesian system and pay hardly any attention to distinctive microscopical characters. I feel convinced that these are of fundamental importance and that any book that may be subsequently published on the British Basidiomycetae will have to be based on these characters. Between the years 1906 and 1908 Dr Franz von Hoehnel and Viktor Litschauer published some interesting papers on the Corticia under the title "Beiträge zur Kenntnis der Corticieen" which clearly showed that the species in Corticium and allied genera could only be recognized by a careful microscopical examination. They showed that many specimens published in several well-known exsiccati were wrongly named, and often belonged to other genera, whilst in a few instances they were based on scraps of paint or insect workings. von Hoehnel has also published many valuable descriptions of fungi in his numerous contributions entitled "Fragmente zur Mycologie" which have appeared in the Transactions of the Vienna Academy (Sitz. der Kaiserl. Akad. Wissenschaft.) between the years 1902 and 1914. I would more particularly draw your attention to his

regrouping of the species of Mycena contained in his fifteenth "Fragmente," 1913. In this he rearranges the species on a system based upon the cystidia which we all know are generally present in most of the species of this genus. His classification is founded on their presence or absence, their occurrence on the gill edge only and also on the gill surface, their coloured or colourless contents, their early deliquescence or permanence, and their various shapes. I think it will probably interest you if I show you how this applies to our British species according to his investigations.

A. Cystidia small, oval, shortly setulose, *soon entirely deliquescent*: *Mycena viscosa* (Secr.) Maire, *Mycena epipterygia* (Scop.) Fr.

B. Cystidia permanent.
   1. With coloured contents.
      α. On gill edge only.
      Sharply pointed above, ventricose below: *Mycena avenacea* (Fr.) Schroet., *Mycena rosella* (Pers.) Fr., *Mycena rubromarginata* Fr., *Mycena sanguinolenta* (A. & S.) Fr.
      β. On gill surface also.
         a. Globose, oval, setulose: *Mycena elegans* Fr.
         b. Narrow, conical: *Mycena pelianthina* Fr.
         c. Acutely pointed above, ventricose below: *Mycena rosella* (Pers.) sensu Schroeter.
   2. With colourless contents.
      α. On gill edge only.
         a. Globose, oval, generally setulose: *Mycena corticola* (Pers.) Fr., *Mycena galericulata* (Scop.) Fr., *Mycena rugosa* Fr., *Mycena tenella* Fr., *Mycena vitrea* Fr., *Mycena vulgaris* (Pers.) Fr.
         b. Oval, with few setae: *Mycena dissiliens* Fr.
         c. Oblong, vesiculose: *Mycena pura* (Pers.) Fr.
         d. Bluntly conical above, ventricose below: *Mycena lactea* (Pers.) Fr., *Mycena luteoalba* (Bolt.) Fr., *Mycena metata* Fr., *Mycena polygramma* (Bull.) Fr., *Mycena rorida* Fr., *Mycena stannea* Fr.
         e. Cylindrical, filamentose: *Mycena filopes* (Bull.) sensu Schroet., *Mycena hiemalis* (Osb.) Fr., *Mycena polygramma* (Bull.) Fr., *Mycena stylobates* (Pers.)Fr.
         f. Vesiculose, conical: *Mycena zephira* Fr.
         g. Short, filamentose, indistinct: *Mycena citrinella* (Pers.) Fr.
         h. Long, filamentose, often ventricose below: *Mycena flavipes* Quél., *Mycena rubella* Quél.

i. Variable in shape (filamentose to conical or vesiculose): *Mycena leptocephala* (Pers.) Fr., *Mycena stannea* Fr., *Mycena sudora* Fr., *Mycena alcalina* Fr.

β. On gill surface also.

a. Thick, rigid, filamentose: *Mycena gypsea* Fr.

b. Bluntish, conical: *Mycena vitilis* Fr.

c. Short, clavate, vesiculose, setulose: *Mycena crocata* (Schrad.) Fr.

d. Acutely conical, containing many oil drops: *Mycena parabolica* Fr., *Mycena speirea* Fr.

e. Filamentose to fusiform, contents watery: *Mycena galopus* (Pers.) Fr.

C. Cystidia absent: *Mycena cyanorhiza* Quél.

I have cited this last which is not British because I know of no British example of the section. I am aware that some observers consider there are no cystidia in *Mycena epipterygia* (Scop.) Fr. but I can confirm von Hoehnel's statement that they are present in very young specimens. Ever since I obtained a copy of this paper I have carefully examined a considerable number of the cystidia in the commoner species of Mycena and in the main I agree with von Hoehnel's description of them, but I certainly differ from Schroeter with regard to *Mycena filopes* (Bull.) Fr. This species is characterized by broadly pyriform, or obovate, minutely spinulose cystidia which form a compact layer on the gill edge, and are not cylindrical and pointed as Schroeter has described them. To appreciate the correct shape of the cystidia it is necessary to work with freshly gathered material as they alter considerably in form when kept in tubes or a tin box for a comparatively short time, and this applies more especially to the cylindrical and filamentose ones. In his sixteenth "Fragmente" von Hoehnel also lays considerable stress on the fact whether the basidium is provided with two or four sterigmata. I admit that this is a feature of some diagnostic value but I should be very loath to separate one species from another on this character alone, because one often notices basidia with two or four sterigmata on the same gill and in the Corticia and allied genera it is a very common feature. I think it is much better to describe a species as having basidia with two to four sterigmata than to make the form with two sterigmata a variety as Lange does with *Mycena lactea* (Pers.) Fr. var. *pithya* A. & S., or to treat it as the type as Lange does with *Mycena filopes* (Bull.) Fr. and refers the one with four sterigmata to the forma *tetraspora* Lange. In the following year, 1914, Lange published his revision of "The genus Mycena" in his "Studies in the Agarics of Denmark" which appeared in the Dansk. Bot. Ark.

Bind 1, No. 5. He therein regroups the species of Mycena with smooth spores into two divisions based on the characters of the cystidia. In the first, the CILIATAE, he places all those having their free apical portion conical, cylindrical, hair-shaped or subulate, and in the second, the GRANULATAE, he puts all those having clavate pyriform or obovate cystidia beset with warts or setae on their free portion. This is a very workable division of this genus and one that I think we might very usefully adopt, but it will take some time before we can work out the form of the cystidia in all our British species and therefore I crave the assistance of all our members in so doing.

In 1914, the eminent American mycologist, Professor E. A. Burt, commenced his splendid series of monographs on the genera of the Thelephoraceae of North America. Up to the present these include monographs of the following genera: Thelephora, Craterellus, Cyphella, Exobasidium, Tremellodendron, Eichleriella, Sebacina, Hypochnus, Septobasidium, Coniophora, Aleurodiscus, Hymenochaete and Stereum. These monographs are models of careful work and original research and are indispensable to a thorough knowledge of this group, and I feel that all students impatiently await the completion of this series. In 1909, l'Abbé H. Bourdot and A. Galzin began an account of the "Hyménomycètes de France" in the Bulletin de la Société Mycologique de France, vol. xxv, and several other instalments have appeared in succeeding years, but it is unfortunately far from completion at the present time. It is based on Patouillard's classification but is especially valuable for the wealth of detail that it gives respecting the Thelephoraceae, Hydnaceae, Auriculariaceae, Tremellaceae and Tulasnellaceae. They have in a great measure remodelled the definitions of the species of Thelephoraceae and resupinate Hydnaceae and in conjunction with the investigations of v. Hoehnel, v. Hoehnel and Litschauer, l'Abbé Bresadola and Professor Burt compelled us to reinvestigate our own British species in this group. It is somewhat unfortunate that Bourdot and Galzin have not followed the laws of international nomenclature and that they rarely condescend to say what name the new species described by them was previously known by to the older school of Friesian mycologists. Take *Odontia bicolor* (A. & S.) Bres. as an instance which Miss Wakefield has clearly shown was known to Berkeley by the name of *Grandinia mucida* Fr. Again, the well-known *Peniophora hydnoides* Cke. & Massee has no cross reference in their synopsis of that genus but suddenly crops up as *Odontia conspersa* Bres., a specific name that cannot be maintained under any rules of nomenclature. It is however a very important work and I think we are very grateful to Miss Wakefield and Mr A. A. Pearson for

applying these intensive studies to the investigation of our British resupinate Basidiomycetae. I consider also that I am justified in offering to them on your behalf our very hearty congratulations on having two new British species named in their honour by l'Abbé Bresadola and l'Abbé Bourdot, viz. *Corticium Wakefieldiae* Bres., and *Corticium Pearsonii* Bourd.

In 1915 Lange published further monographs on the genera Amanita, Lepiota and Coprinus in his "Studies in the Agarics of Denmark" (see Dansk. Bot. Ark. Bind. 2, No. 3), but it is only to this last one that I propose to draw your attention because I think the groups into which he has divided the species of Coprini are very natural ones and well worthy of adoption. He arranges them in three sections:

I. Comati: Pileus when young covered by filaments made up of cylindric or irregularly branched cells;

II. Farinosi: Pileus when young covered with meal or glistening particles formed of globose cells; and

III. Nudi: Pileus naked. Veil none.
- α. *Setulosi*: Pileus sparsely and minutely bristly or setulose under a lens.
- β. *Glabri*: Pileus quite bare and without setulae.

Lange unfortunately only deals with about half the number of the British species, so there is plenty of work for our members to do in determining to which section the omitted ones should be referred.

In 1907 the eminent French mycologist Emile Boudier published his "Histoire et classification des Discomycètes." This work further elaborates the excellent system of classification of the Discomycetae which this great master had first outlined in 1885 in the Bulletin de la Société Mycologique de France, 1, 91. The great superiority of this system over all others is due to the fact that it is based on a careful investigation of all the microscopical characters, and related genera are brought into a natural instead of an artificial sequence. Boudier was the first mycologist to draw attention to the importance of the mode of dehiscence of the ascus in this group, and this constitutes the basis of his two main divisions, the *Operculeae* dehiscing by a circular opening furnished with a lid, and the *Inoperculeae* dehiscing by a simple apical orifice. In his original essay Boudier only assigned a few species to each genus but in his later work he gives a complete list of them. This made his scheme much easier to work with and shortly afterwards I ventured to record our British species under his genera in the lists of specimens collected at our forays. In 1913 Mr J. Ramsbottom made it available for the use of British students by publishing in our

Transactions an excellent "List of the British species of Discomycetes arranged according to Boudier's system, with a key to the genera." We are I fear very conservative in our ideas of the classification of our British Fungi as it appears that close on thirty years had elapsed between the first publication of Boudier's system and its adoption and now almost twenty years have passed since Patouillard propounded his revision of the Basidiomycetae. In 1910 Boudier completed his "Icones Mycologicae ou Iconographie des Champignons de France principalement Discomycètes." This is undoubtedly the very finest illustrated work on fungi that has ever been issued, and the minute microscopical details, beautifully portrayed on each plate, make it of the greatest value and assistance in the identification of species, and indispensable to the student of the Discomycetae.

In 1919 Mr A. D. Cotton and Miss E. M. Wakefield gave us a very valuable "Revision of the British Clavariae" (see Trans. Brit. Myc. Soc. VI, 164) founded on fourteen years' study of this genus by the former, and I think we are much indebted to them for giving us such a reliable monograph of our British species. I must however protest against *Clavaria dissipabilis* Britz. being treated as a synonym of *Clavaria inaequalis* (Müll.) Fr. because the former is distinguished from the latter by having echinulate spores. Cotton in a paper published in 1907 (see Trans. Brit. Myc. Soc. II, 163) maintains that this spore character must be attributed to *Clavaria inaequalis* (Müll.) Fr. and alleges that "the first reference to the character of the spores appears to be in 1882, in which year Karsten (Ryss. Finl. Skand. Hattsv. II, 171) describes these bodies as elliptical, $10 \times 5\,\mu$," but I feel confident that such eminent mycologists as Boudier and Patouillard would never have published their description of *Clavaria similis* in 1888, unless they had been satisfied that the true *Clavaria inaequalis* (Müll.) Fr. possessed smooth spores. It is generally admitted as Cotton states that *Clavaria similis* Boud. & Pat. is synonymous with *Clavaria dissipabilis* Britz. and must give way to the latter on the ground of priority. Cotton and Wakefield in the Monograph, p. 190, say "it is possible that a species with smooth, elliptical spores occurs on the Continent, but if so it is obviously very rare and cannot be regarded as representing the old and well-known *Clavaria inaequalis*." But the French assign a smooth ovoid spherical spore to *Clavaria inaequalis* (Müll.) Fr. Quélet in his "Flore Mycologique de la France" published in 1888 describes the spores, at p. 461, as "ovoïde sphérique, $7\,\mu$," and Bourdot and Galzin in the "Hyménomycètes de France" which appeared in 1910 in the Bulletin de la Société Mycologique de France, XXVI, 217, define the spores as "ovoides-sphériques, apiculées, $7–9 \times 6–8\,\mu$,"

and under *Clavaria similis* Boud. & Pat. describe the "spores hyalines à guttule huileuse, subsphériques, hérissées d'aiguillons coniques, 4–7 × 4·5 μ" and further add that this species is "plus commun que *Clavaria inaequalis.*" Thus if we allowed Cotton's contention to prevail we should have the absurdity of *Clavaria inaequalis* (Müll.) Fr. being represented by an echinulate spored species in England and a smooth spored species in France. I may also add that I possess a painting made by my wife in 1889 of a Clavaria which I referred to *inaequalis* (Müll.) Fr. and this had smooth, globose spores, 6–7 μ in diam., so it would seem clear that we also have the smooth spored form and it is probably not uncommon as I do not suppose that even one per cent. of these specimens are ever subjected to microscopical examination.

We have had numerous presidential addresses and papers showing the great progress that has been made in the study of the Uredinales, Ustilaginales and Perisporiales. We now know that many of the biological species on our cereals are confined to one host and it is only occasionally by means of a bridging species that they are enabled to attack another host: that certain strains of our cereals are immune or less liable to be affected, this immunity depending not so much on the inability of the spores of the parasite to effect an entrance but is rather due to some reaction on the host's part, probably in the nature of an enzyme, that arrests their further development. In 1904 Eriksson brought forward his well-known mycoplasm theory as the cause of epidemical rust and mildew outbreaks that otherwise could not be explained. His view is that this mycoplasm exists as a form of protoplasm within the cells of the host and that it lives symbiotically in the tissues of the plant until such time as favourable conditions, climatic and others, cause it to pass into the typical mycelial stage from which the spore-beds of the Uredo are formed. Great advances have been made by numerous workers in our knowledge of the heteroecious rusts and the "Monographia Uredinearum" by P. and H. Sydow contains an exhaustive account of this group, most of which has been embodied in W. B. Grove's "British Rust Fungi" published in 1913. For a reliable list of the British Uredinales we are indebted to Mr J. Ramsbottom who prepared the list for our 1912 Transactions (see Trans. Brit. Myc. Soc. IV, 98).

I know of no real progress being made during this period with regard to a reclassification of the Pyrenomycetae, which is at present based, as you all know, on an artificial scheme almost as crude in character as the Linnean system was for phanerogams: but notwithstanding this crudeness it is rather a remarkable fact and one I think to be deplored that no British text-

book has appeared dealing with this branch of mycology since Cooke's "Handbook of British Fungi" in 1871. It must not however be imagined that their study has been neglected as the contrary is evidenced by the numbers of additions to the British list that Miss A. Lorrain Smith has annually recorded in our Transactions and I feel that we are very greatly indebted to her for the magnificent series of papers on our micro-fungi which have so greatly extended our knowledge of the British species and are an undying monument to her skill and knowledge of these groups. Mr A. D. Cotton and Dr S. K. Sutherland have also given us invaluable papers on our Marine Pyrenomycetes (see Trans. Brit. Myc. Soc. III, 92 and IV, 147 and 257), and it is only in recent years that fungi have been discovered growing on our seaweeds.

In 1915 Mr J. Ramsbottom gave us an exhaustive "List of the British species of Phycomycetes, with a key to the genera" (see Trans. Brit. Myc. Soc. v, 304). He enumerates over one hundred and sixty species whereas the last British list, published by Massee in 1891, "British Fungi: Phycomycetes and Ustilagineae," included only about ninety British examples, and so we see that our knowledge of this group had almost doubled in this period. Mr Ramsbottom prefaced this list with a catalogue of the nine British species included in the Phytomyxineae or Plasmodiophoraceae, and the Acrasieae. It was only last year that Mr Norman G. Haddon made an addition to the former group by his interesting discovery of *Tetramyxa parasitica* Göbel which he found growing on *Ruppia rostellata**.

These last two orders belong to the Mycetozoa, but are not included in the magnificent and exhaustive Monograph of the Mycetozoa by Mr Arthur Lister and Miss Gulielma Lister which was published under the auspices of the British Museum in 1894 and 1911. This Monograph is beautifully illustrated, has accurate camera lucida drawings of all the microscopic details of each species founded on an examination of the types, and is provided with elaborate keys to the genera and species. I only regret that no such accurate text-books have yet appeared to assist the student in the various branches of mycology. The appearance of this Monograph greatly stimulated interest in these minute animals and this is proved by the fact that the first edition of the "Guide to the British Mycetozoa" issued in 1895 only enumerated one hundred and nineteen species whereas the fourth edition, published in 1919, has increased this to one hundred and eighty-one, an addition of over half the original number.

* We have since learned that this species was recorded by Mr D. A. Boyd in 1887 from Chapelton, West Kilbride (Trans. Nat. Hist. Soc. Glasgow, II, p. xxxvi (1888)).

During this period our knowledge of the life-history of many of our numerous fungal diseases, which attack fruit trees, bushes, cultivated crops and vegetables, has greatly increased. Hardly a day now passes but what some new species is added to the already long list of these pests. Various remedies are suggested for their suppression, amelioration, or avoidance. At the present time the planting of immune varieties and strains of fruit trees and vegetables, and the employment of protective washes to prevent infection seem to be most favoured. I think we may congratulate ourselves upon the fact that it was due to the strenuous efforts of two of our members, Prof. E. S. Salmon and Mr F. T. Brooks, that Government action was taken to suppress the Gooseberry Mildew, *Sphaerotheca morsuvae* B. & C., and the Silver-leaf disease of our plum and other fruit trees attributed to *Stereum purpureum* (Pers.) Fr.

With regard to the cytology of fungus reproduction I feel that this requires no comments from me as it was ably dealt with by Dr Harold Wager in his luminous Presidential address on "The significance of sex and nuclear fusions in the fungi" (see Trans. Brit. Myc. Soc. VI, 307) delivered to you only two years ago. Mr J. Ramsbottom has also kept our members well abreast with the most recent investigations on this subject by his voluminous, exhaustive and able summaries of the results obtained throughout the world (see Trans. Brit. Myc. Soc. III, 354; IV, 127, 249; V, 85, 271 and 441).

I claim also that an immense advance has been made in the knowledge of our larger British fungi by the members attending our annual spring and autumn forays. Since the meeting at the Boat of Garten in September, 1900, complete lists of all the species gathered have been published, and each year increases the value of these as a reliable source upon which to base the data for the distribution of our fungi.

Perhaps the most noteworthy forays that have been held may be considered to be those at Forres and Baslow. The former was held in conjunction with the Cryptogamic Society of Scotland from the 12th to the 19th of September, 1912, under the Presidentship of Miss Gulielma Lister. At this meeting seven hundred and twenty-six species of fungi and eighty-one species of mycetozoa were collected. It is not fair to compare this number with those collected at other autumn forays because a certain number of our members arrived at Forres several days before the meeting and their collections are included in this large total. It is clear however that the climatic conditions were very favourable to their growth, because in 1919 at the autumn foray held at Baslow from the 22nd to the 27th of September, under the Presidentship of Dr Harold Wager, only three hundred and

ninety-one species of fungi and forty-five species of mycetozoa were met with although many of the members were detained there for a week longer owing to the railway men's strike. The chief cause of this poor record was undoubtedly the early advent of severe night frosts, which killed the mycelium after it had begun to run. At the autumn foray held at Baslow, Derbyshire, from the 27th of September to the 2nd of October, 1909, under the Presidentship of Professor M. C. Potter, the Society was greatly honoured by the attendance of several distinguished French mycologists including Professeur René Maire, Mons. E. Peltereau and Mons. and Mme. E. Simon. It was due to their kind assistance that many important additions were made to the British fungus flora. These included *Omphalia Allenii* Maire, named in honour of my friend and fellow-member Mr W. B. Allen, one of the most able discriminators of species in the Basidiomycetae, and *Leptonia Reae* Maire, named in honour of my wife as a tribute of his admiration for her paintings of our fungi. Over five hundred and thirty-three species of fungi and forty species of mycetozoa were passed in review during the week, and Dr René Maire subsequently created a new variety of *Leptonia serrulata* (Pers.) Fr. for the form that exactly corresponded with the painting by Berkeley erroneously reproduced as the type in Cooke's Illustrations of British Fungi, No. 355, t. 333, and based on specimens collected at Spondon in Derbyshire, calling it var. *Berkeleyi* Maire in honour of that distinguished mycologist.

I found on referring to our Transactions for the exact date of this meeting, that Professor M. C. Potter delivered a very instructive Presidential address on "Bacteria in their relation to plant pathology" (see Trans. Brit. Myc. Soc. III, 150). Professor Potter pointed out that many plant diseases were caused by these parasites, in many other cases they were found in association with parasitic fungi, and that it was often very probable they were the primary cause of the infection. Professor H. Marshall Ward in an early Presidential address (see Trans. Brit. Myc. Soc. I, 124) insisted on the importance of these organisms in converting xylose into some other form of sugar more easily assimilated by fungi. We all know that many orchids and heaths can only be successfully raised from seeds that at an early stage are brought into contact with the symbiotic, endotrophic mycorrhiza, and that some observers allege that the presence of bacteria is essential to the germination of the spores of some species of Coprinus and mycetozoa. The study of the bacteria causing plant disease is a very important and interesting one, but I fear that it is impossible for many of our members to take up this branch of mycology because

the student needs a well-equipped laboratory for his investigations. In 1909 Professor A. H. R. Buller published his "Researches on Fungi," which is an invaluable work embodying the results of original research on the physiology of our fungi and it is to be hoped that he will favour us with another volume on the same subject.

I have now passed in brief review the most important features of our mycological progress that has been made since the foundation of our Society. I think that we can congratulate ourselves on the fact that, although many of our junior members were called away during the war, we managed to carry on, to hold our autumn forays and to publish our Transactions as usual. We have emerged from that trying time stronger in number than we ever were before and I feel confident all our members will continue to advance our knowledge and uphold our motto "Recognosce notum, ignotum inspice."

THE PARASITISM OF NECTRIA CINNABARINA (CORAL SPOT), WITH SPECIAL REFERENCE TO ITS ACTION ON RED CURRANT.

With Plate I.

By J. Line, M.A.

General.

This subject has been investigated by a number of workers, but although the very familiar fungus is regarded in this country as a frequent parasite on many broad-leaved trees, no critical investigation appears to have been made, nor has it been considered as the cause of any serious damage.

Mayr(1) demonstrated by actual infection experiments as long ago as 1883 that the fungus could become parasitic on maple: although he did not use pure cultures of the fungus there seems no reason to doubt the general accuracy of his results.

He pointed out that the normal method of infection was through a wound, and that the fungus could not penetrate the living phloem and cortex. He also showed that the fungus when established in a side branch could readily pass over into the healthy wood of the main stem, and that the pathological effect was primarily due to the blocking of the vessels by the hyphae, causing death of all parts above the point affected. The stem so killed was then easily and rapidly invaded by the fungus, although the first blocking process might take two years or considerably more.

It is almost impossible to reconcile these results with those of Wehmer(2) who from observations on the lime and hornbeam in 1894 concluded that the fungus became parasitic, but that it was strictly confined to the cortical regions, never entering the woody tissues. He considered that Mayr was completely mistaken in his observations or that he was working with another fungus.

Durand(3) in 1897 described the appearance of the fungus on red currant in the U.S.A., his descriptions of the disease tallying exactly with the symptoms observed during 1919 and 1920 in this country. He considered that it was acting as a parasite, but although he performed infection experiments with pure cultures of the fungus, he does not record any of his results. It is well known that coral spot often occurs on dead branches of otherwise healthy red and black currant bushes in this country. It was pointed out to the writer in 1919, by Mr F. T. Brooks, that it had never been shown how much of the die-back observed was due to the primary action of the Nectria, and how much to the action of one or other of the fungi often associated with it.

An investigation was therefore started in order to settle if possible

(1) to what extent the fungus may be regarded as a parasite, particularly on the red currant;

(2) its normal method of infection and method of growth in the host tissues;

(3) whether any differences in power of infection could be detected between different strains of the fungus.

Field Observations.

A number of orchards were kept under fairly close observation during the years 1919 to 1921, and a very large number of the bushes were found bearing the stromata of Nectria on one or more of their branches. Other commonly occurring fungi were *Collybia velutipes* and *Fomes Ribis*. A few bushes were found bearing *Stereum purpureum* and Botrytis. No experimental work was done with these fungi, but a short summary of observations made on them will be found elsewhere.

During this preliminary examination of the bushes, single branches on apparently healthy bushes were often found showing signs of wilting of the leaves. In some cases this was observed just after the leaves had expanded, but others did not become wilted until about flowering time. Later on branches bearing nearly ripe and quite normal fruit were found suddenly to become wilted (Figs. 1 and 2). Such branches when left on the bush were observed to lose all their leaves during the summer,

and to become completely dried up: in all about fifty branches were kept under close observation from the time wilting was first observed, and in every case the branch which had lost its leaves became covered with the pink stromata of Nectria during the following winter.

A number of similar branches were removed from the bushes as soon as the wilting was observed. When cut open it was found that a brownish green region was present in the wood at the base, extending almost across the branch, leaving a small area of white and healthy wood, with a corresponding area of healthy cortex external to it.

This discoloured portion could always be traced either to a wound in the branch itself or more commonly to a dead side branch; in many cases these dead portions already bore stromata of Nectria.

The discoloured portions of wood and cortex were found to be full of fungus mycelium extending up to the edge of the white and healthy wood, the vessels and tracheids being choked up in the darker parts with hyphae and gummy material. This characteristic discoloration of the wood was observed by Mayr in the wood of Norway maple, and he considered the gummy liquid represented the product of solution of part of the cell wall by the fungus. Fig. 3 shows the hyphae in the wood cells taken from the edge of the discoloured zone; it is seen that in the early stages of invasion the fungus appears incapable of invading the living ray cells; later on these also become filled with hyphae. It was never found that the fungus advanced in the cortex before the wood was blocked up, in fact there seemed no evidence that it could effect an entrance into any living cell in a normal healthy condition.

Experimental Work.

A. *In the laboratory.*

Twelve typical branches were selected with discoloured portions attached to them, but no visible stromata or signs of the presence of any fungus upon them; after thorough scrubbing they were placed under sterile conditions in jars of water under bell jars. In six weeks every branch began to show the pink stromata of Nectria breaking through the bark, commencing round the discoloured regions. (Control branches developed a little Cladosporium under these conditions.)

Portions of the wood from different parts of the discoloured regions were removed from another batch of branches under sterile conditions and were transferred to Petri dishes of sterile agar jelly.

FIG. 1.

FIG. 2.

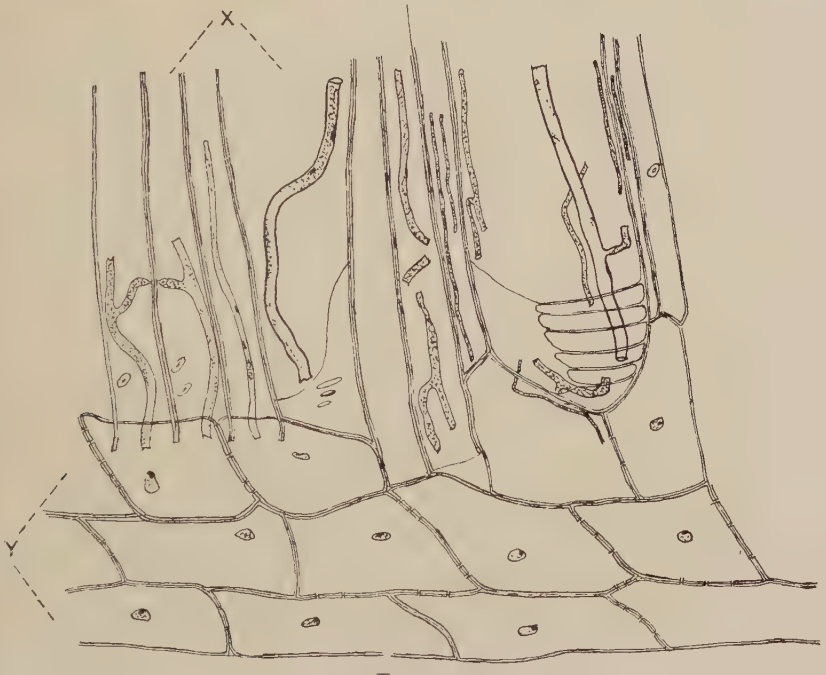

FIG. 3.

FIG. 1. First signs of wilting of twig of red currant.
FIG. 2. Later stage of wilting of twig of red currant. Note the nearly ripe fruit on this branch.
FIG. 3. Long. radial section of wood of red currant. Mycelium of *Nectria cinnabarina* invading the healthy wood. Note absence of hyphae from the ray cells. ×350 approx.
X = xylem elements. *Y* = ray cells.

From a number of these dishes nothing developed, but in all cases where the piece of wood had been taken from the edge of the dark zone a vigorous fungal mycelium grew out from the chip into the jelly. Portions of this mycelium could be readily removed to other media, and in all such cases the mycelium proved to be that of Nectria.

From these observations and experiments it seemed probable that the Nectria was able to cause the wilting and death of branches on the currant when once established in the bush. It is worth recording that in no single case did Botrytis develop from the cultures made from the branches, and it was observed comparatively rarely in the orchards. *Collybia velutipes* was extremely common in one orchard on older bushes, and was then frequently associated with Nectria; it was rarely found on younger bushes and did not develop on any of the bushes from which wilted branches were removed. About a dozen bushes in all were found bearing fructifications of *Fomes Ribis*; these were in every case sickly looking plants stated to be at least forty years old.

B. *Infection Experiments in the field.*

The common occurrence of the fungus on so heavily pruned a plant as the red currant, as well as its behaviour on other plants, would lead one to suppose that its normal method of entering the host was through a wound; in view of some recent work on the method of infection of the apple canker fungus it was decided to test the power of the coral spot fungus to penetrate uninjured branches, through either the leaf-scars, lenticels or bud scales.

It was thought possible that different strains of the fungus might be found which would show different powers of infection. A series of cultures of the fungus was started with the usual precautions as to freedom from other fungi, bacteria, etc. No difficulty was experienced after a time in making single spore cultures from both conidia and ascospores, and these were obtained from a number of different sources. Cultures were set up on many different media under a variety of conditions in the hope that the formation of perithecia might be induced. So far none have been obtained, although nodules exactly resembling them in appearance and to some extent in structure are obtained in old cultures. These cultures are being carried on with other media at the present time, in the hope that the success of Miss Cayley with *Nectria galligena* may be repeated.

This fungus shares with *Nectria cinnabarina* the character that in many gelatinous media the mycelium buds off spores laterally in great profusion.

Infections were made on red currant (200), fig (20), lime and horse-chestnut (20) in a number of different ways and at different times of the year. Wounds made were of course protected from chance contamination from outside sources.

The cortex and wood were inoculated at varying depths; mycelium and spores were placed on leaf-scars of different ages and between the scales of resting buds. In most cases the mycelium from wood block culture was used, but conidia and mycelium from agar cultures, ascospores and conidia from natural sources were also used.

It was found in the case of the red currant that the fungus made very little progress indeed in the cortex and phloem, or in the wood of a healthy branch. When severely wounded by a deep incision some headway was made, but in two cases only did the fungus establish itself and produce fructifications on the branch.

As a rule a small discoloured area was formed round the point of inoculation and this did not increase. Callus formation rapidly covered the wound with healthy tissue, and by the following year the only trace of the inoculation was a small dark area in the wood.

In the case of the horse-chestnut and lime several branches were found in which the fungus made rapid headway, fructifications of Nectria being formed in about three months. In other cases on the same trees the fungus was apparently isolated and unable to make headway.

The observations on naturally occurring infections suggest that the fungus can attack healthy wood when it is established in a dead portion adjoining the healthy part. A series of infections were therefore made on artificially killed branches projecting from healthy branches. Some were killed by severe longitudinal slitting, others by means of a steam jet or the flame of a spirit lamp. All were covered up for some days before inoculation.

The fungus was found to establish itself fairly readily in these killed side shoots, stromata being developed sometimes in six weeks. After a period which was variable, but never less than six months, the fungus began to work its way into the main stem, stromata appearing on the side from which the shoot projected. In time the whole stem was blocked, exactly the same symptoms being observed as have been described previously from field observations.

Conclusions.

It would seem probable that this fungus resembles others which have been described recently in that it cannot establish

itself directly in healthy tissues, but that it can do so after a period spent on a dead portion of the host.

It is thought that the harmful action of the fungus is entirely due to its growth in the xylem elements, causing death of living cells above the infected area owing to water shortage.

No evidence was obtained that it could ever enter a living cell until the cell was at any rate partially cut off from its water supply. No ill effects appear to be felt by the leaves and flowers on a stem, which may be almost completely blocked with Nectria at a lower level, until they suddenly show signs of wilting. It therefore would seem improbable that any toxic substance is secreted by the fungus which can affect living cells in advance of the fungal hyphae. Experiments are being conducted with a view to further elucidation of this point.

It is commonly observed that the attacks of the fungus are much more frequent on red currant than on either black currant or gooseberry. The former, which is normally somewhat heavily pruned, furnishes a number of dead spurs each year, and these are observed to be the starting-points of the fungus in the great majority of cases. The time of the actual invasion of the main stem is not apparently related to the time at which the first infection took place. Observations show that the older bushes suffer more serious damage from the fungus than younger and more vigorous bushes of the same variety, but it is plain that the fungus has in most cases been growing for several years on the older bushes before actual death of branches on a large scale occurs.

Very little information could be obtained as to the names of varieties in the orchards, although it was certain that differences in the extent of attack by the fungus under the same conditions did exist. Further work is being done in collecting evidence as to the different varieties, and the effect of soil conditions.

Summary.

(1) The fungus was not found capable of effecting an entry into uninjured plant tissues.

(2) It can occasionally establish itself when introduced into a wound in certain woody plants, more readily in the case of the lime and horse-chestnut than in the case of the red currant, but it usually failed to do so under the conditions of the experiments.

(3) Its normal method of attacking the red currant is by spreading through the wood cells from a dead portion into the healthy wood.

(4) Its harmful action in the first place is due to the stoppage

of the wood cells by the fungal hyphae, thus causing wilting and death of all parts above the point affected.

(5) No differences in power of infection or in behaviour in culture were observed between strains of the fungus isolated from different sources.

I should like to take this opportunity of thanking Mr F. T. Brooks for the time he has spent in directing the work and for many suggestions and criticisms, and Professor Seward for laboratory accommodation.

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ORCHID MYCORRHIZA*.

With Plates II—VII.

By J. Ramsbottom.

Introduction.

One of the most interesting phenomena in biology is that generally known as *symbiosis*—the living together of two organisms in close association. It is usually considered that this intimate relationship is of benefit to both components. Many examples occur in the plant kingdom. The lichen is probably the best known of these, being a composite plant formed of a fungus and an alga in definite union. Other well-known examples are the bacteria (*Pseudomonas radicicola*) living in the root nodules of Leguminosae, and the Ginger-beer plant†, of which the lumps are composed of a yeast (*Saccharomyces pyriformis*) and a bacterium (*Bacterium vermiforme*). An intimate union can also occur between plant and animal, as in the case of the marine worm *Convoluta*, in the body of which an alga is always present,

* Reprinted from Messrs Charlesworth and Co.'s Catalogue, 1922. The Editors desire to thank Messrs Charlesworth for permission to reprint this article and for the loan of the blocks.

† The Ginger-beer plant is, at the present time, being widely distributed over the country as "Californian Bees," "Macedonian (Salonika) Bees," "Mesopotamian Bees," "Palestine (Jerusalem) Bees," "Wine Bees," "Water Bees," "Balm of Gilead," etc.

and as in the larvae of certain aphids, coccids, etc., where yeasts occur as more or less definite structures.

Mycorrhiza.

That the roots of many plants have the threads or mycelia of fungi associated with them has become very well known during the last eighty years. It is of interest to find that cells containing fungi were first figured in an orchid (though not very clearly) by Link* in 1840, who observed them in the young seedling (protocorm) of *Goodyera procera*. He did not hazard a guess as to their nature—his idea being that the cells were filled with colourless granular material which finally disappeared.

At the beginning of the forties of last century the naturalists of this country who were curious in botany were very interested as to whether *Monotropa Hypopitys* was parasitic on the roots of beech in a manner similar to *Lathraea*. In 1842 we have T. G. Rylands† writing "On the nature of the byssoid substance found investing the roots of *Monotropa Hypopitys*." Rylands concludes that "the 'byssoid substance' is really fungoid, and performs no essential function in the economy of the *Monotropa*." It is, however, to Reissek‡ (1847) that we owe our first real knowledge. He examined numerous plants and came to the conclusion that fungi were normally present within the cortical cells of the roots of various flowering plants, being best developed in the underground roots of orchids. In these he studied most of the native and several exotic genera. He found that in *Orchis Morio*, for example, the fungus was present in almost all the cortical cells, whereas in the tropical species the fungal masses were arranged singly at the periphery. The presence of fungi was most frequent in underground roots, less usual in superficial ones and very rare in aerial roots exposed to the light. Moreover Reissek attempted to extract the fungus from the roots. In those days of imperfect technique it is not so surprising that he failed as that he should have made the attempt. The fungus he obtained he named *Fusisporium endorhizum*: it is probably one of the common saprophytic species of *Fusarium* so abundant in soils.

Another type of association between fungus and root is also well known, particularly in forest trees. Here the fungus mycelium forms a sort of mantle round the root, in contrast to being within the cells of the cortex. Apparently Hartig first

* H. F. Link, Icones selectae anatomico-botanicae, II, p. 10, t. VII (1840).

† T. G. Rylands, On the nature of the byssoid substance found investing the roots of *Monotropa Hypopitys*. Phytologist, I, pp. 341–8 (1842).

‡ S. Reissek, Über Endophyten der Pflanzenzelle, eine gesetzmässige den Samenfäden oder beweglichen Spiralfasern analoge Erscheinung. Naturwiss. Abhandl. von W. Haidinger, I, pp. 31–46 (1847).

noted this type in 1840 in the extremities of the rootlets of *Pinus sylvestris* although he mistook the hyphae for branched intercellular canals surrounding the internal cells such as are known to exist in the corky layer of the root cortex in *Juniperus* and *Thuja*. Rootlets so infected are most frequently coralloid in appearance. Gasparini in 1856 noted that such rootlets in *Castanea* and *Corylus* were surrounded by fungal hyphae.

The term *mycorrhiza* was coined by Frank* in 1885 for the fungus-roots. Even at that date it was known that in some plants the fungus occurred in rhizomes as well as roots (e.g. *Neottia*), and since then many cases have been found for which the term is quite a misnomer (e.g. Liverworts). It is a convenient term, however, and it is better to accept it with an extended meaning rather than to restrict it to those cases for which it is etymologically sound. Frank gave special names to the two types mentioned above. He used the term *endotrophic* mycorrhiza for those forms in which the fungus occurred within the tissues of the host, and the term *ectotrophic* mycorrhiza where the fungus hyphae surrounded the rootlet as a sheath. These are convenient general terms, but it is well to remember that the two types are not absolutely distinct, as is seen, for example, in *Monotropa*, which had been well described by Kamienski in 1883. Mycorrhizas, mainly endotrophic, have been described, either as usual, or occasional, in various Liverworts, Mosses, Horsetails, Club Mosses, Adder's Tongues, Ferns, Conifers and Flowering Plants: and in Algae apart from Lichens we have cases of constant association of fungi and seaweeds, as, for example, in *Ascophyllum* and *Pelvetia*, which each have their attendant *Mycosphaerella*. The antiquity of such associations is seen in the fact that they occur in the fossil plants *Rhynia*, *Hornea* and *Asteroxylon* from the Lower (or Middle) Devonian —vascular cryptogams which from their simple structure and age are of the greatest theoretical importance. Weiss (1904) moreover recorded mycorrhiza in fossil roots from the Lower Coal Measures for which he proposed the name *Mycorrhizonium*, and Osborn (1909) found fungus mycelia in the inner cortex of *Amyelon radicans*, the root of *Cordaites*.

Orchid Roots.

As we have seen, fungi have been recognised in the roots of orchids since 1847. A transverse section of an infected root taken just above the root-cap shows the fungus in the cortical cells (Fig. 1). The distribution is more or less constant in the

* A. B. Frank, Ueber die auf Wurzelsymbiose beruhende Ernährung gewisser Bäume durch unterirdische Pilze. Ber. d. deutsch. bot. Gesell. III, pp. 128–145 (1885). Lehrbuch der Botanik, Bd. I (1892), p. 264.

same orchid, but varies in different genera. It is only in the young root where root-hairs are present that the fungus is, as a rule, recognisable as such. The epidermal cells are not infected. The fungus usually enters the root through the root-hairs, but in some species it apparently is able to make use of any portion of the piliferous layer. The hyphae* pass through the external layers to a more or less definite zone, where they reach their maximum development, rapidly spreading and completely filling the cells. If an exodermis be present the hyphae pass through the thin-walled transfusion or passage cells. The first two or three cortical layers of the root are thus generally free from fungus except where the hyphae of infection pass through them: even in these there is no balling of the mycelium in the cells. In some genera (*Habenaria*) (Figs. 1 and 14), the fungal zone occupies roughly the third and fourth layer of cortical cells. In other genera (*Neottia* and *Epipogum*) the fungal zone of the root occupies three layers or so of cells separated from the endodermis by about half-a-dozen cell rows. In other cases practically the whole of the cortex is occupied (*Cymbidium* and *Odontoglossum*). The central stele is never infected, the mycelium not entering the endodermis. The fungus also never infects the cells of the growing point of the root. Infected roots do not always show the endophyte in all their length, neither is it invariably present in a continuous zone. Infection does not generally occur once for all, but the hyphae from the soil infect the roots in several places and if the fungal zone be of several cells thickness it is frequently seen as patches in transverse section. Nor, as a rule, are all the roots of an orchid infected. Aerial roots particularly are free from fungus, the only exceptions being where the roots are applied to the soil and are without chlorophyll. Such a case is shown in Fig. 15. Aerial roots can sometimes be found in such a position with the exposed portion green: in these circumstances if infection occur the fungus is restricted in distribution to the portion of the root without chlorophyll. In addition to cells containing chlorophyll those containing tannin, mucus, raphides and other crystals are never invaded by the fungus. Lateral roots are more frequently infected than main roots and in those genera with numerous roots (*Orchis*, *Ophrys*) according to Stahl only one out of three of the roots arising from the rhizome have fungus present in their cortex. Moreover, certain genera such as *Listera* and *Epipactis*, which have their chlorophyll particularly developed, seem to be irregularly infected, whereas plants poor in chlorophyll, e.g. *Limodorum* and *Corallorhiza*, are well fungussed. All

* Janse has shown that in *Lecanorchis javanica* the infecting hyphae are sometimes united into a mycelial ribbon.

orchids so far investigated possess mycorrhiza, with the single exception of the saprophytic *Wullschlaegelia aphylla**. Large numbers both of native and exotic species have been studied—Wahrlich†, for example, examined over 500 of the latter cultivated at Moscow.

Since the earliest workers, e.g. Reissek, it has been known that in some cells at least the fungus becomes changed from its original thread-like structure into glary yellow amorphous masses. In fact, it was owing to this phenomenon that the fungal nature of the cell infections of these roots was not at first generally realised. Wahrlich paid special attention to the changes which took place, and most investigators of orchid roots since then have taken note of them. Magnus‡ working with *Neottia* in which the alterations are well marked gave a clear description of the metamorphosis. He distinguished two main types of infected cells and held that there were no transitional stages. In the one type which he calls "digesting cells" (Verdauungszellen) the fungus always degenerates; in the other type, the "host cells" (Pilzwirthszellen) the fungus remains alive in the cells which lodge it and is thus able to hibernate. Magnus states that *Neottia* shows a more or less definite arrangement of these two types of cells, the digesting cells forming an outer and an inner and the host cells the middle layer. Such a regular arrangement is not usual in orchids—even in *Neottia* it is doubtful—and host cells are absent in certain native genera, such as *Goodyera*, and in most tropical forms. Bernard and Burgeff have also studied the question of the fungus digestion—the former mainly in seedlings, the latter principally in the root of *Platanthera chlorantha*. Before a hypha enters a host cell the nucleus of the latter increases in size. This action at a distance is also seen in the fact that starch disappears from the cells. The nucleus in the neighbourhood of the hypha becomes hypertrophied, often becomes modified in form and has increased attraction for stains. Where mycelial influence is great the nucleus becomes amoeboid and sometimes disintegrates: this would seem to indicate a parasitic action on the part of the fungus. The digesting cells are clearly recognisable by the degenerating mass which more than half fills the cells. The increase in the size of the nucleus is also a character as it becomes about four times its original diameter, i.e. roughly sixty times the

* Further investigation is needed on this plant. MacDougal first recorded that *Cephalanthera oregana* was free from fungus, but later found a somewhat sparse and intermittent infection.

† W. K. Wahrlich, Beiträge zur Kenntnis der Orchideenwurzelpilze. Bot. Zeit. XLIV, pp. 481, 497 (1886).

‡ W. Magnus, Studien an der endotrophen Mycorrhiza von *Neottia Nidus-avis* L. Jahr. f. wissensch. Bot. XXXV, pp. 205–272 (1800).

volume. The nuclei become amoeboid and put out pseudopodia which serve to attack the hyphae. The hyphae only stain slightly: they increase in diameter up to about double and also in length. The development in some cases is so great that the cell is quite filled with the thick mycelial mass and the nucleus is crumpled by the hyphae. Enclosed by the pseudopodia the latter gradually lose their outline until frequently they cannot be distinguished from protoplasmic trabeculae. The victorious nucleus then assumes a round form and normal volume and reconstitutes its chromatin network. The endophyte is reduced to an amorphous yellowish clump with indistinct contour, and is absolutely devoid of life: it is surrounded by a cellulose membrane. It would seem that as the root ages the clumps finally disappear. After the formation of the clump starch often reappears in the cell. Burgeff states that the fungus in the host cells can re-attack digesting cells when similar stages are again gone through. We shall return to the question of digestion when we consider the seedling.

Germination of Seeds.

The difficulty in germinating the seeds of orchids is one which has been known for a considerable number of years. In fact, it was not until 1804 that any orchid seedlings were described, when R. A. Salisbury figured those of *Orchis Morio* and *Limodorum verecundum*. Later, many botanists such as Link, Irmisch, Beer, etc., added to our information concerning the stages of development. Orchid growers evolved the method of sowing seeds on the soil containing the parent plant*, and it was in this manner, or some modification of it, that most of the hybrids known in horticulture were raised. The facts known, i.e., the difficulty in germinating seeds unless placed on orchid soil and the presence of fungi in the roots, led many to suspect that the fungus was concerned in some way with the success or failure of germination.

We have mentioned that when Reissek recognised the fungal nature of the cell inclusions, he attempted to isolate them. This attempt, long before the days of bacteriological technique, was bound to end in failure and the fungus he isolated was a species of *Fusarium*, a genus which has been time and again proclaimed as the consort of the orchid root. (The genus *Nectria* also has often been assumed to be the endophyte.) It is to Noël Bernard that we are indebted for our chief knowledge of the facts of orchid germination. This brilliant young French investigator began his studies on mycorrhiza in 1899, and they extended until his death in 1911. His first investigation was on the germina-

* I believe Dominy of Messrs Veitch and Sons introduced this practice.

tion of *Neottia*. In 1902 in his thesis "Étude sur la tubérisation" he mentions that orchid seeds can germinate only in the presence of the root fungus and that the seedling is infected from its earliest stages. Realising the importance of this fact he turned his attention to investigating it thoroughly and following the various ramifications of the subject. Bernard's great work, "L'évolution dans la symbiose. Les Orchidées et leurs Champignons commensaux," appeared in 1909. In the same year a comprehensive work by Burgeff was published entitled "Die Wurzelpilze der Orchideen." Both these investigators succeeded in isolating the fungus from the orchid root and growing it on nutrient media. Orchid seeds germinated without difficulty on having the appropriate fungus supplied to them. In describing the course of events full use has been made of the work of Bernard and Burgeff, this being supplemented by observations made by the late Mr J. Charlesworth and the writer.

Joseph Charlesworth (1851–1920).

It will probably not be considered out of place here if I venture upon a few remarks concerning my friend the late Mr Joseph Charlesworth. In the year 1913 I was invited to Haywards Heath to see his results in raising seedlings by what he styled the "pure culture method." He had succeeded in eliminating many sources of error and had achieved remarkable and consistent results in raising *Odontoglossum* and its allies by sowing seeds on nutrient media in which the appropriate fungus was growing. The probability that the mycorrhizal fungus in some way affected the germination of orchid seeds had influenced him for many years and he had earned his great reputation as a hybridist by his success in raising hybrids by modifications of the methods in common use. In an account of a visit to his establishment in 1906 it was written "Here is a veritable seedling land, thousands and thousands of them," and in 1909 "The raising of *Odontoglossum* and allied genera has become a very important business, and there are thousands of seedlings in existence. Messrs Charlesworth are reducing it to a system." It was to one so successful by the older methods that Bernard's work made such a strong appeal, and he eventually decided to adopt the system. His culture flasks were sufficient testimony to the success of the laboratory method when placed upon a commercial scale. One was not prepared to find, however, that at the same time he had, after the age of sixty, become so embued with the new spirit as to have purchased microscopes, microtomes, ovens, stains, books, etc., and become proficient in microscopic technique. (The photomicrographs illustrating this paper are all taken from his preparations.) Naturally

he did not restrict his newly acquired activities to studying orchids, but the main part of his laboratory work dealt with them, and he was especially interested in the seed from its first formation and in the relations between fungus and seed in germination. The whole of the slides were generously placed at my disposal. We, however, drew up a scheme of collaboration and mapped out a series of investigations, which unfortunately had to be discontinued owing directly and indirectly to the war. When, in 1920, we were both again free to resume the work he was a sick man and beyond application to research.

I should wish to repeat here for the benefit of those orchid lovers who knew so well one part of his accomplishments that the other part was equally good. The fact that he should commence laboratory work at such a late age is as surprising as is the success which he attained practically unaided. To a botanist trained in the schools many of his expressions appeared whimsical, but when he termed the small cells at the distal end of an *Odontoglossum* seed the "soul of the plant," it was as a result of finding that it was there eventually that both stem and root were laid down—and he had a happy knack of coining such expressions and, one may add, a certain persistency in using them. If his early days had been spent in acquiring a knowledge of academic botany rather than in connection with his father's wool business, there can be no doubt that the name of Joseph Charlesworth would have been writ large in the annals of British science. As the firm of Messrs Charlesworth are carrying on the traditions of their late chief, it may be possible at some future date to complete and put on record certain of the investigations; and it is hoped it may be possible to carry out the original plan in which his knowledge of orchid culture would have played an essential part.

Orchid Fungus.

Bernard in his first attempts to isolate the fungus from orchid roots obtained a species of *Fusarium*. When, however, he succeeded in extracting the right fungus he established a criterion which enables one to settle without doubt whether the true fungus has been isolated, viz. that the endophyte is able to bring about the germination of the seed.

The fungus, when living within the cells of the plant, shows no characters which give a clue to its systematic position, but when it is grown on nutrient media it shows additional stages of development which are characteristic.

When extracted from the root and placed in a culture medium the fungus always appears to behave in the same way. The fungus spreads over the surface by the apical growth of its

septate filaments. Meanwhile lateral branches arise and anastomoses take place between the hyphae. Later, balls of hyphae appear here and there in the culture and on the sides of the tube or flask containing them, usually some distance from the ends of the hyphae. These balls are very similar to those which appear in the cells of the root, being formed by the rolling up of the ends of young growing filaments, and often becoming very compact. When seen in the host cells this method of growth suggests adaptation to the needs of the special environment, and its presence in cultures might lead to the supposition that the character is so impressed upon the fungus that it also shows it when living free. The character is, however, not rare in the group in which we must classify this fungus.

As the mycelium becomes older shorter filaments arise with very short and swollen segments, which are apparently rich in food reserve. (It was this appearance that caused Bernard to place the fungus in the genus *Oospora* when he first studied it.) These filaments ramify abundantly and in certain forms anastomose amongst themselves and give rise to yellow or brown sclerotia* (Figs. 4 and 5), small spherical bodies formed of intertwined and massed hyphae. These structures are capable of withstanding drought and other inclement conditions and are remarkably tenacious of life. Bernard has pointed out that these swollen filaments are very like those which occur in *Rhizoctonia violacea* Tul.† which is common on potatoes, lucerne and other crops, where it forms small, blackish, irregular sclerotia, and he considers that the orchid fungi fall into the same genus. He classed the fungi obtained from about twenty orchids as three species, *Rhizoctonia repens*, *R. mucoroides* and *R. lanuginosa*. The first, which was by far the most commonly isolated (*Laelia*, *Laelio-Cattleya*, *Spiranthes*, *Paphiopedilum*, *Cymbidium*, *Aerides*, *Bletilla*, *Coelogyne*), does not form sclerotia. *R. mucoroides* was found in *Phalaenopsis* and *Vanda*, and *R. lanuginosa* in *Odontoglossum* (Figs. 4 and 5). Burgeff, unaware of Bernard's latest results, proposed a new genus *Orcheomyces* for the reception of the orchid fungi. He fully describes fifteen species, naming them after the orchid from which he obtained them and mentions another fourteen by name: he divides them into five main groups.

A discussion of the different systematic interpretations given by Bernard and Burgeff would be out of place here and for convenience the more generally adopted name *Rhizoctonia* will

* Sclerotia are known in all groups of fungi, often reaching considerable dimensions, e.g. the size of a man's head in *Polyporus Mylittae* (the "black fellows' bread" of Australia).

† *Corticium vagum* B. and Br. var. *Solani* Burt.

be used. The diversity in the number of species is simply a case of the usual "lumping" and "splitting." Bernard found in his experiments that fungi obtained from different sources, but to which he gave the same specific names, varied somewhat in their behaviour, and it is quite probable that these physiological distinctions are related to slight morphological differences. Bernard later recognised certain of Burgeff's species as falling within his, e.g. *Orcheomyces Sambucinae, O. mascula, O. insignis* and *O. Luddigi* were regarded by him as *Rhizoctonia repens*—but he apparently took into account merely the gross characters of growth.

The endophytic fungus is able to ferment cellulose, which accounts for its ability to penetrate cell walls. Burgeff made a study of the physiological characters of the species he isolated. He found that they were able to absorb carbohydrates in the form of sugars, these being in all cases transformed by a diastase-invertase in some species, maltase in others. Having regard to the prevalent ideas as to the function of mycorrhizal fungi it is of particular interest to note that these forms are apparently unable to fix free nitrogen: the nitrogen of organic compounds, such as peptone, can be made use of as a source of nitrogen: ammonium compounds are better assimilated than nitrates. By growing cultures in the dark and in an atmosphere devoid of carbon-dioxide he established the fact that the carbon compounds of the soil can suffice as a source of carbon.

Bernard in his experiments found that the fungi if grown in culture gradually became inactive. Cultures two years old were quite unable to bring about germination. Burgeff, on the other hand, found that his cultures after twenty-six and twenty-eight months retained their power. In connection with this point a culture of a root fungus which had been regularly cultivated for at least eight years, though not used during that time for germination, was recently tried. A very feeble germination occurred in certain of the tubes. As the activity of the fungus when it was first isolated is not known, it is impossible to say whether there is any decrease in intensity, though this is probable. The gradual attenuation with final loss of activity noted by Bernard may be a consequence of "staling" through too infrequent renewal of cultures. He found that the intensity of an attenuated form can be increased by extracting it from a plant which it had been successful in germinating.

Germination of Seeds—*continued.*

The seeds of orchids are very small, the embryo being frequently only just visible to the naked eye*. They possess a

* The embryo in Fig. 2 is approximately 200μ, i.e. c. $\frac{1}{125}$ inch.

single integument which is in the form of a characteristic network (Fig. 2) which varies somewhat in shape and structure in the different genera. On sectioning the seed (Fig. 3), or on viewing when stained and mounted whole, there is seen to be no differentiation into cotyledon, stem, radicle, as is almost universal in flowering plants*. It appears to be most usual for the cells at the suspensor end of the seed to be somewhat larger than at the upper end (Fig. 3), though this is not always the case (*Cypripedium*). Sometimes the suspensor cells are permanent (*Cattleya*)—the suspensor is the stalk by which the developing seed is attached and nourished—at other times they disappear before the seed is matured (*Phalaenopsis*). Seeds taken from the capsule under sterile conditions and sown on ordinary substrata where no fungus is present do not as a rule develop. Generally they merely swell and become green (*Odontoglossum*) though sometimes even this does not happen (*Epidendrum*); in other cases they may form stomata and the rudiments of hairs (*Cattleya*). The only case so far known in which any considerable development can take place under these conditions is *Bletilla hyacinthina* where Bernard found that thin slender seedlings developed with distinct leaves. The food reserve of orchid seeds is most frequently oil, part of which becomes transformed into starch. The reserve food comes to its end just as the seed commences to become green. This is usually after three or four months, during which time very little, if any, nutriment can be obtained from the substratum, as absorbing hairs are lacking. If no fungus infection take place then, the seedling dies. It is somewhat surprising that after the production of chlorophyll death should occur rather than autonomous growth by aid of photosynthesis: the seedling appears to form chlorophyll as a sort of last despairing effort.

If, however, the appropriate fungus (i.e. the fungus from the root of the parent or some closely allied plant) be added now at the latest, an extraordinary change takes place. The fungus seems to give an impetus to development.

In the culture flasks it is only in prearranged experiment that infection takes place at such a late stage. The fungus enters the seed usually within a few days. The course of events may be made out from the photomicrographs, which are taken from different genera in order to show the general similarity in the phenomena. Entry takes place at the suspensor end of the seed between the suspensor cells themselves, if such be retained. The cell walls here are unmodified, though the general surface of the

* *Bletilla hyacinthina* shows a rudimentary cotyledon according to Bernard. Treub has indicated a cotyledon in *Sobralia macrantha*, and Pfitzer records a green embryo with a differentiated cotyledon in *Platyclinis glumacea*.

seed is slightly cuticularized. As we have seen, the cells at the suspensor end of the seed are generally larger, and it is into these that the fungus passes (Figs. 3, 6, 7, 8). The cells are invaded by degrees, the hyphae becoming twisted into a ball in each cell before passing on to the next. Almost immediately the smaller cells at the opposite end of the seed undergo division. It is here that the meristem of the stem is laid down. The meristematic cells in orchids are never entered by the fungus: the only cells capable of division which ever harbour the endophyte appear to be those of the seed where it first enters. Eventually the developing seedling takes on a swollen shape most frequently more or less turbinate (Figs. 9, 10).

Bernard uses the term "protocorm" for this swollen tubercle and regards it as of theoretical importance, as it simulates the protocorms of Lycopods and the colourless underground prothalli of Adder's Tongues, etc. It is of interest to remark that a similar structure, also associated with fungi, occurs in the primitive fossil plant *Hornea* from the Devonian. The fungus remains restricted to the larger cells and follows in the wake of their division. The epidermal layer is free from infection. Meanwhile the rapid division taking place in the smaller cells at the anterior end of the seed gives rise to the young stem apex and the first leaf (cotyledon). About the time this young leaf becomes visible to the naked eye the cell-division has become extended along the axis and the beginning of the central stele is seen (Fig. 10). In this manner the young root is formed and begins to absorb its way through the tissues of the protocorm (Fig. 11). Finally it passes out into the soil (Fig. 12). In no orchid studied in the present series (*Odontoglossum, Oncidium, Cattleya, Cymbidium, Vanda, Cypripedium,* etc.) does the developing root when passing through the tissues enter the fungal zone nor do the hyphae extend into the root. In fact there is often a suggestion of a delimiting membrane separating the two areas (cf. Fig. 12). Thus when the root enters the soil it is absolutely free from infection; in none of the usually cultivated orchids does the root receive fungus from the swollen protocorm. Infection takes place from the soil most frequently when the root is about a quarter of an inch in length, the hyphae entering by the root hairs a little behind the region of greatest growth. This throwing off of the fungus, as it were, is repeated in orchids with tubers which do not retain their roots: the tuber is not infected and the new roots receive their fungus from the soil. In fact, in orchids so far studied it is only in the saprophytic *Neottia* that constant infection obtains. Here infection progresses gradually from the widely infected protocorm into the body of the plant, gains the rhizome and infects the successive

roots. The region of infection is thus perfectly continuous throughout the plant from the tip of the protocorm to the base of the inflorescence: as Bernard remarks, according to the evidence the whole of the mycelium harboured by a *Neottia* has for its single origin the mycelial filament which first penetrates the embryo*.

The question arises as to whether root infection *per se* is obligate in orchids with abundant chlorophyll or whether it is a necessary evil. If the latter, one would expect the fungus to be lodged in the roots, though restricted in distribution. As stated above, all the cells entered seem to act as digestive cells in cultivated orchids. Is such digestion a device for protection or for nutrition?

What has been happening to the fungus during these stages? The course of events was first followed by Bernard. As we have seen, the fungus enters at the suspensor end of the seed by the cells of the suspensor near the point of attachment (*Odontoglossum*) or by the cells of the pole of the embryo where the suspensor is attached (*Vanda*). There appears to be an attraction, though feeble, towards the place of entry. The first filament entering the seed apparently excludes all others, though it may be of an attenuated form and unable itself to bring about germination. Bernard compared this with vaccination: the infection immunizes the seed. In successful germinations the fungus, after seed entry, follows the development of the cells forming mycelial balls in all the posterior portion of the seedling. According to Bernard, when the fungus reaches the cells bordering on the meristematic region digestion takes place. This is regarded as being analogous to phagocytosis such as occurs in animals where the white corpuscles of the blood attack, engulf and digest any invading micro-organisms: the cells in which the digestion takes place are the phagocytes.

In general these may be regarded as definite cells often recognisable, even before infection on account of their nucleus sometimes becoming lobed. The balling of the fungus in the cells is compared with agglutination, and the manner in which this occurs only in cells of the developing seedling which have achieved their growth is compared with cases of mortal infection where the balling is abandoned sooner or later and the fungus grows on in every direction and invades all the tissues indifferently.

* The association can be even more close under certain conditions. Flower scapes are frequently unable to pierce the humus covering them and the flowers and seeds develop underground, sometimes beneath the root-tufts which produce them. Mycelium apparently from the rhizome of the plant passes up the central cavity of the stem and infects the seeds in the subterranean fruits which are thus able to germinate.

Digestion eventually takes place in all the more deeply lying cells, while the external layers act as host cells. The fungus can pass out of the protocorm by way of the hairs present on its surface.

This application of the theory of phagocytosis is a most attractive one. Gallaud* first suggested the similarity of the function of the digestive cells and that of phagocytes, but it is to Bernard that we owe the working out in detail†. Much investigation on the germinating seed is still needed. Bernard's account of the distribution of the phagocytes is not satisfactory. As the photomicrographs (Figs. 10, 12, 13) show it is not unusual for all the infected cells of the protocorm to be able to digest the fungus eventually.

Germination without Fungus.

How far is it possible to replace the fungus by artificial conditions? Bernard concluded from a consideration of the way in which the endophyte can act at a distance, i.e. bring about changes in cells to which it has not access, that there is a general modification of the physico-chemical properties of the sap which can reach all the tissues. He tried the effect of solutions of salep and saccharose of increasing concentrations on seeds of *Bletilla*, *Cattleya* and *Laelia*. In *Bletilla* where, as we have seen, germination takes place with the formation of slender seedlings in the absence of fungi, in high concentrations most of the seedlings showed thickened protocorms and short internodes comparable with fungus infected individuals. The seeds of *Cattleya* and *Laelia* at low concentrations swell and become green. With higher concentrations development is always much slower and more irregular than with fungi, but one can obtain seedlings of quite normal appearance. As the concentrations increase the development is increasingly better, but more irregular: but there is an upper limit beyond which there is no germination.

Thus it appears that augmentation of the culture medium can, in certain cases, supply the place of fungus action. In fact Bernard states that in the condition of his experiments it was more certain and easier to germinate certain seeds by the action of concentrated solutions than to have recourse to fungal infection. Germination was slow, but very regular, the protocorms had a normal appearance and the seedlings when fairly developed could be transplanted. Experiments showed that *Rhizoctonia* was able to increase the concentration of the solutions in which

* F. Gallaud, Études sur les mycorrhizes endotrophes. Rev. Gén. Bot. XVII, pp. 5 et passim (1905).

† Bernard (1911) also showed that the bulbs of *Loroglossum* contain a diffusible substance which has a fungicidal effect on *Rhizoctonia*.

it grew and Bernard considered it probable that it acts similarly in orchid tissues and increases the degree of concentration of the sap. This problem of autonomous germination recalls to mind that of parthenogenesis—the development of an ovum without the intervention of a spermatozoon. The egg possesses all the substances necessary for activation: the spermatozoon is an inciting cause of these reactions within the egg system on which development depends. Parthenogenesis occurs naturally in certain groups, but it has been brought about experimentally in numerous cases where fertilization normally obtains*, †. Apparently the first successful attempt was made by Tichomiroff in 1886, who stimulated the unfertilized ova of the silk moth to development by rubbing them between two pieces of cloth. Various methods have since been used such as treatment with fatty acids, certain salts such as barium chloride, lipoid solvents such as chloroform, hypertonic and hypotonic solutions, etc.‡.

Another significant similarity is that artificially activated eggs always show a marked slowness in their rate of development, even with the best methods, as compared with the fertilized eggs. This suggests, according to Lillie, some factor that has not yet been successfully imitated in any artificial way. Is it possible that in both cases accessory food factors (vitamines) may play a part? In considering the case of seeds it might be pointed out that there are many instances of peculiar germination known in other phyla. Pinoy§ showed that spores of Myxomycetes such as *Chondrioderma difforme* do not germinate unless bacteria are present. Ferguson‖ discovered that the only way in which she could germinate the spores of the common mushroom effectively was by having a little mycelium of the fungus present in the cultures, and Servettaz¶ found that a species of *Oospora* activated the growth of the moss *Phascum*

* F. R. Lillie, Problems of Fertilization. Univ. of Chicago Science Series (1919).

† Y. Delage and M. Goldsmith, La parthénogénèse naturelle et expérimentale. Paris (1903).

‡ The only case in which parthenogenesis has been induced in the entire vertebrate phylum is in the frog, where Bataillon in 1910, after years of vain attempts, finally succeeded by the exceedingly simple method of pricking the eggs with a fine needle. It is necessary that blood or tissue extract should be carried into the egg by the needle. This method has been abundantly confirmed and tadpoles so obtained have been reared to maturity by Loeb and Bancroft.

§ E. Pinoy, Rôle de bactéries dans le développement de certains Myxomycètes. Ann. Inst. Pasteur, XXI, p. 632 (1907).

‖ M. C. Ferguson, A preliminary study of the germination of the spores of *Agaricus campestris* and other Basidiomycetous fungi. U.S. Dept. Agric. Bureau of Plant Industry, Bull. No. 16 (1902).

¶ C. Servettaz, Recherches expérimentales sur le développement et la nutrition des mousses en milieux stérilisés. Ann. Sci. Nat. 9 sér. XVII, pp. 111–224 (1913).

cuspidatum to a remarkable degree, though the favourable action was of short duration in the conditions of his experiments.

Gastrodia.

An unusual and interesting type of mycorrhiza occurs in *Gastrodia elata**, a non-chlorophyllous orchid widely spread throughout Japan, where it occurs mostly in woods under *Quercus serrata* and *Q. glandulifera*. The full-grown flowering tuber is oblong and slightly curved, attaining almost without exception a length of 10–17 cm. This tuberous rhizome is the whole vegetative part of the plant and consists essentially of parenchymatous cells. Multiplication usually takes place by the tuber. It produces long rhizomes from its apex or node, upon which stalked off-sets are developed. At the end of autumn the mother body and the pedicel of the off-set undergo degeneration, so that the daughter tubercles are set free. Unless the mother tuber has been infected with the necessary fungus the off-sets decrease in size with each successive generation, until they become so much reduced and deficient in food materials that they are incapable of further multiplication. The fungus necessary for proper development is not a microscopic mould as in the other orchids studied, but *Armillaria mellea*, the well-known "honey fungus." This toadstool is extremely common in our woods where it is a most destructive parasite, "indeed more trees die, in Europe at any rate, from attack by this fungus than through any other parasitic agent†." The fructifications are found generally on or near stumps. If the earth beneath the toadstool be dug up it will be found to contain one or more black strands, resembling bootlaces, which are attached to the base of the stem. These rhizomorphs, as they are called, consist of densely compacted fungus mycelium. Further, the mycelium in the wood of the tree itself is first felted and grows up through the cambium to a considerable height: when the tree is dead and the bark has become loosened the mycelium is transformed into a tangled mass of flattened rhizomorphs. Early mycologists considered that they were here dealing with three different species of fungus—the toadstool (*Agaricus melleus*), the rhizomorph under the bark (*Rhizomorpha subcorticalis*) and the rhizomorph in the ground (*Rhizomorpha subterranea*).

It is with the subterranean rhizomorph that we are here concerned. It forms a cylindrical, smooth, black strand, usually 1 to 1·5 mm. in thickness. Its peripheral portion, the so-called cortex, consists of compact, pseudoparenchymatous, brownish

* S. Kusano, *Gastrodia elata* and its symbiotic association with *Armillaria mellea*. Journ. Coll. Agric. Imp. Univ. Tokyo, IV, pp. 1–66 (1911).

† W. E. Hiley, The fungal diseases of the common larch. Oxford (1919).

mycelium with a comparatively thick wall. The middle layer is composed of a bundle of large thin-walled mycelia with numerous septa. The inner cavity of the strand is traversed by a loose bundle of very fine longitudinal hyphae rich in protoplasmic contents.

When the tuber of *Gastrodia* is attacked by the rhizomorph, infection is effected by a sucker-like branch of the strand which penetrates the cortical cell layers, partly compressing the underlying cells and partly dissolving their walls. This mode of infection is, of course, quite different from the ordinary endophytic mycorrhizal type where infection is effected as a rule by a single hypha (cf. p. 31). It very much resembles the manner in which the parasitic *Cuscuta* attacks its hosts, the rhizomorph creeping over the surface of the tuber and giving off the infection branches at intervals. On entering the tuber the hyphae of the various portions of the strand essentially retain their structure. The infected area of the tuber may be divided into three regions, according to the structure of the cells and the nature of the hyphae contained within them. The external region is composed of two or three layers of cells which contain a densely entangled mass of comparatively thick-walled hyphae; the middle region is similarly composed, except that the hyphae are generally thin-walled and of various breadths and often arranged as a pseudoparenchyma; the innermost region has large cells each containing a few, slender, slightly curved hyphae. The three regions correspond to the zones in the rhizomorph. The hyphae of each region show characteristic alterations. They are permanent in the first region; in the second they undergo self-disorganization; while in the third they are mostly consumed by the cells of the host. The mode of development of the fungus in the middle region simulates the ordinary clumping seen in most orchids, but the course of events is different in that the protoplast is consumed by the hyphae before their collapse takes place. The destruction of the protoplast shows the parasitic properties of the hyphae. The cells of the inner regions are apparently metabolic centres of the orchid where the food materials are elaborated. The nucleus and cytoplasm undergo remarkable alterations, and secondary products appear indicating considerable activities. After the disappearance of the hyphae the nucleus resumes its original form and structure, while the cytoplasm again becomes fibrous and vacuolate. Starch grains disappear from all the mycorrhizal cells, to reappear in the inner region with the cessation of metabolic activity.

The association of tuber and rhizomorph takes place quite occasionally. If a tuber forms mycorrhiza it can give rise to a full grown off-set which remains dormant during the winter and

develops the inflorescence axis in the following year: otherwise no flowers are produced.

So far no results have been published as to the germination of the seeds of *Gastrodia*. One would expect that fungal infection is necessary for seedling development, but whether the fungus is a form like *Rhizoctonia* or whether there is some adaptation by which *Armillaria* becomes operative remains to be seen. In either case the facts will be of the greatest theoretical interest.

The course of events in *Gastrodia* gives some support to the idea that the relation of fungus and orchid is primarily one of parasitism on the part of the former. At times the rhizomorph attacks tubers and destroys them in a manner similar to that in which it treats potato tubers. Usually, however, the fungus is kept well under control and its hyphae prevented from spreading beyond their apportioned region—and even so being absorbed by the orchid cells. It is difficult to see what benefit the fungus can gain under these conditions. The subterranean strands are apparently unable to obtain nutriment from the soil, their function in the usual life of the fungus being that of "runners." It would seem that *Gastrodia* has turned the attack of these into one of service for transmitting nutriment from the oak stumps to which the fungus is attached, for its own benefit: a colourless saprophyte unable to grow or to flower without the aid of one of the most destructive parasites known!

Number of Seeds and Distribution of Fungus.

When one sees the dense masses of seedlings thriving in the culture flasks one contemplates as to the course of events under natural conditions. The enormous numbers of seeds which are usually produced in the capsules of orchids must have struck the most casual observer. "Not that such profusion is anything to boast of; for the production of an almost infinite number of seeds or eggs, is undoubtedly a sign of lowness of organisation. That a plant, not being an annual, should escape extinction, chiefly by the production of a vast number of seeds or seedlings, shows a poverty of contrivance, or a want of some fitting protection against other dangers." Darwin* estimated that in *Cephalanthera grandiflora* a single capsule contained 6020 seeds and that, therefore, a plant with the usual four capsules would have 24,080 seeds. Similarly *Orchis maculata* had 6200 seeds in a single capsule, and thus a plant having the not unusual number of thirty capsules would produce 186,000 seeds: "As this orchid is perennial, and cannot in most places be increasing, one seed alone of this large number yields a mature plant once

* C. Darwin, Fertilisation of Orchids (1862).

in every few years." In order to retain the number of individuals of a species stationary it is only necessary that one mature plant should be produced during the period of growth of the parent—if more occur the species will tend to oust out all other species. "Linnaeus has calculated that if an annual plant produced only two seeds—and there is no plant so unproductive as this—and their seedlings next year produced two, and so on, then in twenty years there would be a million plants....It would suffice to keep up the full number of a tree, which lived on an average for a thousand years, if a single seed were produced once in a thousand years, supposing that this seed were never destroyed, and could be ensured to germinate in a fitting place*." To give an idea of what the above figures for *Orchis maculata* really mean Darwin worked out the possible rate of increase. "An acre of land would hold 174,240 plants, each having a space of six inches square, and this would be just sufficient for their growth; so that, making the fair allowance of 400 bad seeds in each capsule, an acre would be thickly clothed by the progeny of a single plant. At the same rate of increase, the grandchildren would cover a space slightly exceeding the Isle of Anglesea; and the great grandchildren of a single plant would nearly (in the rate of 47 to 50) clothe with a uniform green carpet the entire surface of the land throughout the globe"—and as *O. maculata* is perennial, the parent plant would still be alive!

But even these numbers in our native orchids are much exceeded by those of tropical species. Scott estimated that a capsule of *Acropera* contains 371,250 seeds and, judging from the number of flowers borne by the plant, the total number of seeds for an individual would be 74,000,000: Charlesworth estimated 825,000 seeds for a single capsule of *Cymbidium Traceyanum*: Muller 1,756,440 seeds for a single capsule of *Maxillaria*. It appears to be a general biological rule that where the conditions of successful germination are difficult of attainment a prolific number of seeds (or spores) are produced and, *vice versa*, where the requirements are not of a specialized nature, a smaller number occur.

In the case of orchids it seems not unlikely that the enormous seed production is in some way related to the fungus question. Their small size, their lightness, their net-work integument and the presence in some genera of elaters ensure their effective dissemination. But unless the necessary fungus be to hand no germination occurs—the seed may develop to a certain extent, but it does not produce roots unless the appropriate fungus enters its cells.

So far, however, we know nothing of the distribution of these

* C. Darwin, Origin of Species (1859).

fungi in nature except so far as they occur associated with rooted orchid plants. Probably most people are aware that fungi of all kinds are present in the soil, but few realize in what enormous numbers they occur and the manner in which some are restricted to the soil. Hagem* calculated that in a gram of soil from a potato field, 350 spores of *Rhizopus stolonifer* and 250 each of *Mucor sphaerosporus*, *M. nodosus*, *Absidia cylindrospora* and *Zygorhynchus Moelleri* were present; and these numbers are much exceeded by *Penicillium* (90–95 per cent. of spores in uncultivated soil according to Sopp†) and other Hyphomycetes. Traaen‡ calculated that from 10,000 to 120,000 spores of *Geomyces vulgaris* and from 1000 to 20,000 spores of *Humicola fuscoatra* occur in a gram of soil. Much work has been done recently on the biological activities of such fungi, attention being paid chiefly to cellulose destruction and the possibility of nitrogen fixation. It is extremely probable that certain of the forms isolated are capable of acting as mycorrhizal fungi, though none have apparently been recognised as such. Further it is possible to isolate *Rhizoctonia* from the soil in the immediate neighbourhood of orchid plants growing wild (as also from the soil of pots containing cultivated orchids): but notwithstanding the large number of species of soil fungi isolated it does not appear to have been found, or at least recognised, by any investigator. We are thus lacking in data as to the distribution of orchid fungi in the soil. Since, however, Bernard isolated *Rhizoctonia repens* from many European orchids and showed it to be the commonest endophyte amongst cultivated species, it must be of world-wide distribution, since in order to account for the distribution of the orchids it is necessary to assume that this particular fungus must occur practically wherever orchids grow.

Ericaceae.

A family of plants which is usually linked with orchids as showing the same constancy of fungal infection is the Ericaceae. Frank early realized that the relation between the fungus and flowering plant in these two families is a particularly close one. In certain ericaceous plants he remarked on the absence of root-hairs, the absence of, or reduction in, the amount of cortical tissues, the reduction of the root-cap, and the masses of fungus mycelium in the enlarged cells of the epidermal layer. Ternetz§

* O. Hagem, Untersuchungen über Norwegische Mucorineen II. Skrifter Vidensk.-Selsk. Christiania. I. Math.-Natur. Kl. No. 4 (1910).

† O. J. O. Sopp, Monographie der Pilzgruppe *Penicillium*. Idem, No. 11 (1912).

‡ A. E. Traaen, Untersuchungen über Bodenpilze aus Norwegen. Nyt Mag. Naturvidensk. LII. pp. 19–121 (1914).

§ C. Ternetz, Über die Assimilation des atmosphärischen Stickstoffes durch Pilze. Jahrb. f. wissensch. Bot. XLIV, pp. 353–408 (1907).

was successful in isolating the fungi from certain species and growing them in pure culture, constantly obtaining the same fungus from the same species of flowering plant. All the fungi belonged to the genus *Phoma**—one of the Fungi Imperfecti, but of a totally different group than is *Rhizoctonia*—and were apparently morphologically and physiologically distinct. She showed that infection of *Calluna* took place in the seedling and also found infection in a case of viviparous germination in *Andromeda*.

Rayner† working with *Calluna vulgaris* was able to show that the full development of the seedling was dependent upon the presence of the mycorrhizal fungus—there is here an "obligate symbiosis" of a type very similar to that in orchids. Finding that the sterile seedlings were unable to form a root-system she investigated the matter in the manner made classical by Bernard. The seed coats were found to become infected while the seeds are still in the ovary. Delicate branched hyphae are present in the cells of the ovary wall, in the tissue of the central column and in the funicles of the seeds. Branches of this mycelium grow across from the cells of the ovary wall to those of the seed-coats, extending from one seed to another. The fungus was isolated and grown in pure culture. It proved to be a pycnidial form similar in all respects to the genus *Phoma*. Sterile seeds sown on this develop normally, whereas in its absence the seedlings merely form a few reddish or chlorotic leaves, but no roots. Infection of the seedling root takes place at, or immediately after, it emerges and may begin at the tip by hyphae forcing their way between the cells of the apex, though more usually it occurs simultaneously at several points. The mycelium immediately becomes intercellular and infection spreads rapidly from cell to cell. Some hyphal branches grow out and infect fresh rootlets as they develop; others form a tangled skein of fine hyphae in the superficial cells. One of the most interesting points of the story is, however, that the fungus does not remain confined to the roots but infects the whole of the young seedling. In the subaerial parts the mycelium does not develop so extensively on the surface of the plant, nor do the hyphae become balled up in the superficial cells as in the roots, but are irregularly distributed in the tissues. In the mature plant likewise the fungus is not confined to the roots but is present in the tissues of the stem, leaf, flower and fruit. The hyphae can also be seen ramifying among the hairs or closely applied to the cuticle of

* *Phoma radicis-Oxycocci*, *P. radicis-Andromedae*, *P. radicis-Vaccinii*, *P. radicis-Tetralicis* and *P. radicis-Ericae*.

† M. C. Rayner, Obligate symbiosis in *Calluna vulgaris*. Ann. Bot. XXIX, pp. 97–133 (1915).

the epidermal cells: they show no preference for special points of entrance or egress, penetrating with equal ease the cuticularized cells of the epidermis or the base of a hair. The ovary—and later the young fruit—contains mycelium in all parts of the internal tissues. This mycelium infects the seed coats of the developing seeds. The embryo and endosperm of the resting seed are free from infection.

Thus, as in *Neottia*, we are dealing, except in the seed, with a dual organism. The type of association is, however, different from what obtains in the orchids so far studied, where no such distribution has been found—and an analogous constancy apparently only occurs in non-chlorophyllous genera. From the fact that Rayner has recorded the presence of ovarial infection in a number of Ericaceae—Rhododendroideae, Arbutoideae, Vaccinioideae and Ericoideae—it may be that the fungus is similarly distributed throughout the tissues of these plants, and presumably obligate symbiosis is to be inferred.

In no other case has the necessity of the presence of the mycorrhizal fungus for germination been proved. There can be hardly any doubt, however, that such a phenomenon is not restricted to two groups so widely separated as the Orchidaceae and the Ericaceae. What have these families in common? Apart from the similarity in habitat of certain species there seems to be nothing except the smallness of their seeds—and it is naturally to seed characters that one looks in this connection. As we have seen, the seeds of orchids are exceedingly small; reduction in most genera would appear to have reached its limit. In typical Ericaceae the seed is very small, rarely exceeding 2 mm. and often less than half this size. There is a richly developed endosperm in which a straight embryo is embedded one-half to two-thirds the length of the seed, always showing a root, an axis and two cotyledons more or less differentiated. It is also of interest to remark that such genera as *Kalmia* and *Ledum* have a net-work integument to the seed.

Pyrolaceae.

Allied to the Ericaceae is the family Pyrolaceae with the sub-families Pyroloideae and Monotropoideae. In families of flowering plants which show saprophytism and parasitism there usually occur green purely autophytic plants, with typical green leaves and numerous flowers; plants that are purely saprophytic or parasitic, with colourless scales and a reduced number of flowers; and all gradations between. Henderson* instances the

* M. W. Henderson, A comparative study of the structure and saprophytism of the Pyrolaceae and Monotropaceae with reference to their derivation from the Ericaceae. Contrib. Bot. Lab. Univ. Pennsylvania, v, pp. 42–109 (1919).

families Burmanniaceae, Orchidaceae, Gentianaceae and Ericaceae as examples of this. Regarding the Pyrolaceae as a saprophytic sub-family of the Ericaceae we can trace a relation between increasing saprophytism and a more intensive development of mycorrhiza. In the root-tip region we get an ascending series in the amount of fungus present from *Chimaphila umbellata* where the epidermal cells of some roots are without hyphae and other roots with hyphae, but not in every cell, to *C. maculata* with a greater number of the epidermal cells filled with hyphae; in *Pyrola rotundifolia* and *P. elliptica* all the cells are infected, and there is the beginning of intertwined hyphae round the root tip; then in *Monotropa Hypopitys* an increase in the width and extent of the sheaths and a division into two zones—an outer loosely woven mass of hyphae and an inner more compact one—and finally in *M. uniflora* a still greater width of the fungal sheath. In the least saprophytic species the epidermis soon dies off, carrying with it the fungal hyphae as in *Chimaphila* and *Pyrola*, whereas in *Monotropa*, especially *M. uniflora*, the epidermis is still living and filled with hyphae when the root is quite old.

Corresponding with this increase in saprophytism there is an increase in the number of seeds produced and a reduction in their size and structure. "The endosperm in the Pyrolaceae consists of relatively few large cells—the embryo of about twenty-five to thirty cells with no trace of cotyledons. In the Monotropaceae the number of endosperm cells is still less and the cells are larger, the embryo also is very small, composed of only nine or five cells." As these seeds also have their integument in the form of a net-work there is an exceedingly close superficial resemblance to those of orchids.

Comparing the members of the Pyrolaceae as a whole with the Ericaceae it would seem exceedingly probable that their seeds are even more dependent upon infection by the mycorrhizal fungus than are those of their chlorophyllous relatives. It will be interesting to learn at what stage infection takes place and whether or not a close approximation to the more advanced orchid type obtains. It is probable that the fungus will be found to be generally distributed in these plants as in *Calluna*.

Burmanniaceae and Gentianaceae.

The other two families in which mycorrhizas are typically developed are the Burmanniaceae and the Gentianaceae*—in

* "Most of the Orchideae are humus-plants, and it is noteworthy that dicotylous saprophytes, such as the Pyrolaceae, the gentianaceous *Voyria*, and others, show a reduction of the embryo like that of the Orchideae. In *Monotropa* the embryo has but nine cells. The germination of the seeds of these dicotylous saprophytes is unknown. It takes place only in the presence

fact Stahl considered that from this point of view the latter family are as important as the Orchidaceae. Moreover, in these families the seeds are small and numerous, with little reserve food material and no chlorophyll. Further there are the typical gradations from green plants to colourless saprophytes and correlated with this is an increase in number and decrease in size of the seeds, with a change in the embryo until we end in the most reduced examples with little differentiated or formless masses, and an increasing amount of fungus in the roots. The seeds of the saprophytic genera have a net-work integument and in appearance bear a very close resemblance to those of orchids. The Burmanniaceae are closely related to the Orchidaceae, and we should expect that showing so many characters in common there would also be a resemblance in the important one of obligate fungal infection for germination. In the Gentianaceae there are many isolated records of difficulties in obtaining seed germination in some of the genera, and it is common knowledge that many Gentians are difficult to raise from seed. It would seem extremely probable that in this family also the mycorrhizal fungus is necessary for seedling development.

Ceillier* has worked out in detail the relation between the presence of mycorrhiza and small seeds. In certain cases as in Juncaceae the seeds are small and little differentiated, but as they possess chlorophyll they are able to begin photosynthesis immediately on sowing. Small seeds with much reduced embryos also occur in parasitic forms such as *Cuscuta*, *Orobanche*, etc. No fungus is present in these genera, but apparently germination is not successful unless contact is made with the organs of the requisite host. It may be that the stimulus necessary in these cases is analogous to that requisite to bring about root formation in plants with obligate mycorrhizas.

Origin of Saprophytism.

What is the trend of evolution in plants of which the roots are normally infected with endophytic fungi? A general survey of families in which endotrophic mycorrhizas are typically developed shows that it is the rule for these families to have small seeds ill-adapted for successful germination. It has also been proved for orchids and for *Calluna* that the seeds need to be infected by the mycorrhizal fungus before the seedling can

of very special surroundings. Probably the fungi which are found in the roots in symbiosis are essential. The smallness of the seeds allows of a large number being formed, and thus the probability that one of the seeds at least will reach favourable conditions for germination is increased," Goebel, Organography of Plants, Part II, pp. 254 [1898] 1905.

* R. Ceillier, Recherches sur les facteurs de la répartition et sur le rôle des mycorhizes. Thèse, Paris (1912).

produce roots. Further it is in these families that typical saprophytic species occur (if we concede that the Pyrolaceae are saprophytic Ericaceae): in fact the presence of fungi in the roots of saprophytes is so common (the apparent exception being *Wullschlaegelia*), that MacDougal regards these seed-plants as being "saprophytic symbionts*." Without the necessary data it is doubly unsafe to theorise, but it suggests itself that in families adapted to a mycorrhizal habit there is a tendency for the seed to become dependent upon the fungus for successful germination, and there is a correspondingly greater production of seed. It has been customary to associate increasing saprophytism with the greater development of mycorrhizal fungus. May it not be rather that saprophytism has arisen by the mycorrhizal fungus taking over some of the functions necessary in germination and relieving the flowering plant of the need of excessive food production for the developing seed and thus of the necessity for carbon assimilation? (The great amount of fungus in the roots of saprophytes militates against the idea that the root may be simply a lodging-place for the fungus to be at hand for germination and of no use in nutrition.) We see in *Calluna* an almost perfect device for the infection of the seed, and the fungus is generally distributed. The most general infection so far found in orchids is in *Neottia*, which, as has been pointed out above, is most comparable with *Calluna*. But *Neottia* is saprophytic. In chlorophyllous orchids it almost looks as if when the necessary stimulus is given for seed germination precautions are taken to prevent general infection, the primary root even being free. In orchids digestion of the endophyte may also be a means of preventing general infection (though in *Neottia* this property can be easily recognised). Does such a general infection as we get in *Calluna* ultimately lead to saprophytism of the type seen in the Pyrolaceae? Are the events described above in the germination of certain orchids an effort to prevent general invasion and the "perfect symbiosis" of *Neottia*?

Lolium.

A case which recalls to mind that of mycorrhiza—especially having regard to recent discoveries—is that of the grass *Lolium*. The fact that the grains of *Lolium temulentum* contain a layer of fungal hyphae situated between the aleurone layer and the fruit and seed coat was first demonstrated by Vogl in 1898, and since then has been many times investigated in different species

* Johow (1889) places all the known saprophytic flowering plants in the six families Orchidaceae, Burmanniaceae, Triuridaceae, Piroleae, Monotropeae and Gentianaceae. (The Triuridaceae are a small family of tropical saprophytes with the two genera *Sciaphila* and *Triuris* and about forty species.)

of the genus. The latest worker is McLennan* who used *Lolium perenne* for her researches. The fungus is far more common in the genus than has hitherto been thought, and it is remarkably constant. Every seed examined (169 of *L. temulentum* and 115 of *L. perenne*) showed infection. The fungus is endophytic, occurring within the cells. It is present in the embryo sac at, or immediately after, fertilization: thus there is a material difference from what happens in orchids and *Calluna*. The fungus increases in quantity at the expense of the nucellus and the cells of the carpel wall. As the endosperm is formed the fungus is absorbed as a source of food supply for the developing embryo. The ovum is infected before any divisions have taken place in it.

The hyphae already in the very young embryo follow the development of the stem-apex and remain localised in their growth until germination takes place. The growth of the fungus keeps pace with that of the plant: the hyphae, however, are mainly restricted to the growing apex, but can be seen extending for a short distance down the stem. Even at this stage the intracellular nature of the fungus can be demonstrated. Some of the parenchymatous cells of the grass are invaded and used as a food supply by the hyphae. When the inflorescence is formed the fungus is especially abundant at the base of the carpels. The cells so affected do not increase in size, and are only to be distinguished from normal unaffected cells by their different staining properties. It is not till the ovule is well advanced that any great increase in the fungal partner takes place. The fungus has not yet been isolated†. It has been suggested that it is probably a degenerate member of the Ustilagineae (Smuts) or of the ergot type. The former would seem the more likely. Smuts attack grasses very generally and often it is the flower that is infected and later the seed, and thus the whole plant. On general grounds it would appear that the line of development to the stage found would be the gradual subjection of a parasitic fungus such as *Ustilago* rather than the further development of a typical mycorrhiza. An examination of *Lolium* roots shows that no typical endophytic fungus is present—in fact these are peculiarly absent in the Gramineae, though recorded by Schlicht for *Holcus lanatus* and *Festuca ovina* and by Tubeuf for certain moorland grasses—and the area of infection seems limited to the region of the stem apex. Thus, though it would appear at first sight that the progress of evolution had

* E. McLennan, The endophytic fungus of *Lolium*. Part I. Proc. Roy. Soc. Victoria, XXXII (N.S.), pp. 252–301 (1920).

† Fuchs (Hedwigia, LI, pp. 221–239 (1911)) claims to have proved that the fungus is a species of *Fusarium*.

been along a line similar to the *Calluna* type leading to infection of the embryo as apart from the seed-coat, and consequent continuous infection, it is more likely that in the typically non-mycorrhizal grasses such a union has been brought about by a subjection of a seed parasite.

Relation between Fungus and Flowering Plant.

Throughout the preceding pages incidental remarks have been made regarding the relation between the two constituents of the mycorrhizal association. The subject is one of extraordinary interest and of extreme difficulty. It does not seem possible to regard all such associations as being of the same nature or as having arisen in the same way.

As we have seen, Rylands was the first to record fungi in association with roots, though his account is not very clear: his idea that the fungus performs no essential function in the economy of *Monotropa* is one that has had few supporters.

Reissek, who in many ways seemed before his time in his attitude towards the subject, regarded the regularity and permanence of the presence of fungi in orchid roots as of great importance. He apparently considered that they were not absolutely necessary for the life of the plant and suggested that the orchid could generate without the root fungus in the same way that the greater number of flowering plants are able to propagate without flowers.

The gradual realization of the dual nature of lichens brought in its train the conception of symbiosis, but the increasing knowledge as to the nature of fungus-roots played a not inconsiderable part in the growth of the idea.

From the year 1862 Tulasne began to consider the relation between the False Truffle (*Elaphomyces*) and the roots of trees as one not of simple parasitism as he had previously (1841) thought, but one by which both organisms benefited in some way. Pfeffer in 1877 took up this idea of mutual benefit and made it more precise. Other workers—Treub, Goebel, Kamienski—also regarded the relation between fungus and root as of this description. It is to the work of Frank, beginning in 1885, that we owe a proper conception of the widespread phenomenon and a clearly outlined theory of symbiosis between fungus and root. Naturally as more facts both of observation and experiment were obtained Frank's original theory was somewhat modified—originally it was that plants with ectotrophic mycorrhiza did not themselves draw nutriment from the soil, but that the mycelial filaments which completely envelop the absorbent roots procure for it all its nutriment. Such roots always lack absorbent root hairs. The absence of these organs of absorption corre-

sponding to the presence of mycelial filaments suggests that the latter take up the functions of the former. Later, the view taken was that the fungus does not necessarily nourish the roots, but draws its nutriment from the humus of the soil and passes on a portion of this to the roots. In other words the presence of the fungus allows the root to make use of certain substances of the humus that it would be incapable of utilizing in its absence. Another hypothesis which figures largely in the literature of the subject is that of Stahl*. This author endeavours to show that the rôle of the fungus consists in furnishing the plant with mineral nutriment. Comparing plants with and without mycorrhizas he points out certain differences which always appear to indicate a much greater circulation of water in the latter. Thus their roots are strongly developed, they possess numerous root hairs, their leaves transpire energetically and are often provided with water stomata. Further, their tissues are ordinarily rich in starchy matters and poor in sugar, i.e. in a condition favourable for transpiration. The fact that mycotrophic plants transpire less† and are in consequence less well fed in nutrient soils leads to the idea that the service which the fungus renders to the host consists in remedying the insufficiency of transpiration. Stahl imagines that the fungus hands over the products of assimilation of the salts rather than the salts themselves. There exists between phanerogams and fungi growing in the humus of forests, heaths, moors, etc., a competition for the salts which the vegetable débris already contains in a concentrated form. The advantage in this struggle would apparently be on the side of the fungi owing to their mode of life. Plants with very active transpiration are alone capable of struggling with success against fungi in soils rich in humus: plants with feeble transpiration are only able to subsist in these conditions by the help which their symbiotic fungus brings.

Magnus (1900) from his anatomical investigations regarded the digesting cells as serving for absorbing the nutriment of the fungus: the lodging cells, on the other hand, are set apart for the nourishment of the fungus on the cell contents and for its hibernation. This idea would give the classical balance of symbiosis—each component benefiting to an approximately equal degree.

Gallaud regards the communication of the endophyte with the exterior in endophytic mycorrhizas as insufficient to assure to the plant the absorption of nutritive substances. From a

* E. Stahl, Der Sinn der Mycorrhizenbildung. Jahr. f. wissensch. Bot. XXXIV, pp. 539–668 (1900).

† The difficulty in drying orchid plants for herbarium purposes is a result of this.

study of numerous types of infection he holds that the fungus when in the root leads a life independent of the exterior and that it must therefore obtain all its nutriment from the plant. Comparing its mode of life with that of fungal parasites such as Peronosporaceae he decides against its parasitic nature and regards it as a special form of saprophyte—an internal saprophyte.

Ternetz working with the fungi from Ericaceae records as a result of careful experiments that they are able to fix free nitrogen. From a theoretical point of view this is of extreme interest, fitting in well with what is known concerning the bacteria in the root nodules of the Leguminosae, but so many discordant results have been recorded in such studies that it would be well not to accept these without confirmation. Incidentally it may be again remarked that Burgeff was unable to show any such fixation in orchids.

Owing to the totally different complexion that Bernard's work put upon the mycorrhiza question, his views are of particular interest. He regards the fungus in orchids as a parasite: an orchid suffers from a benign cryptogamic malady. Symbiosis for him represents the immunity realized by phagocytosis.

Burgeff on theoretical grounds considers that both orchid and fungus must benefit by increased power of reproduction. He is in general agreement with Stahl as to the nature of the benefit the flowering plant receives. The union arose originally from the ability of the fungus to take up carbon compounds from the soil. The function of the fungus in germination is to introduce a solution of carbohydrates into the seed by means of its enzymes.

Most recent workers on ectotrophic mycorrhizas regard the fungus as parasitic. Fuchs* attempted to inoculate the roots of Abietineae by adding fungus spores to the soil. He did not succeed in his experiments, but regarded the vehemence with which the young plants cut off the infected cells as an effort to prevent the attacks of a parasite.

Weyland† introduced the microchemical method of studying the question and it is probable that from such studies a clearer idea of what is really taking place will be obtainable, by the determination of the localization of nutriment. He considers that the fungus in an ectotrophic mycorrhiza is really a parasite and has nothing to do with symbiosis.

* J. Fuchs, Ueber die Beziehungen von Agaricineen und anderen humusbewohnenden Pilzen zur Mycorhizenbildung der Waldbäume. Bibliotheca Botanica, LXXVI (1911).

† H. Weyland, Zur Ernährungsphysiologie mykotroper Pflanzen. Jahr. f. wissensch. Bot. LI, pp. 1–80 (1912).

Weevers* working from a chemical point of view on the presence of ammonia and ammonium salts in plants established the fact that although ammonium salts were found in abundance in the tubercles of the Leguminosae they were in small quantity or absent in mycorrhizal plants. He holds therefore that if fungus-roots really assimilate nitrogen it must be brought about in a manner different from that in the Leguminosae. Weevers is rather of the opinion that mycotrophic plants are, with the help of their fungus partner, able to utilize fully the organic compounds of the soil.

McDougall†, working with ectotrophic mycorrhizas of forest trees formed by the association of toadstools with the roots, considers that they are not in any sense symbiotic associations but must be considered as instances of parasitism by the fungi.

Rexhausen‡ studied ectotrophic mycorrhizas by the microchemical method. He considers that the fungus and the root together form an osmotic unit for the absorption of nutrient salts. These are probably made soluble for the root by the fungus. This gathering up of nutrient salts is first used by the fungus for its own benefit. The mycorrhiza is not a fixed symbiotic condition, but is dependent upon the biological condition of the soil. Where the conditions are not suitable for the growth of the fungus it acts as a parasite on the root and may damage it severely, as it cannot be kept in check. Where the fungus is well nourished it can be easily withstood by the root. Thus in good soils the mycorrhiza gradually disappears or, at all events, the fungus part becomes less.

It will be apparent from the above that many somewhat diverse theories have been put forward to account for the fungus-root association and many modifications have been proposed. No purpose would be served here by entering on a detailed criticism: the only general one we would suggest is that no benefit can result from pushing the old idea of mutual and equal advantages of the two components to its extreme. Referring only to orchids it seems most reasonable to regard the condition as having arisen from parasitic attacks by the fungus. This seems beyond doubt in the exceptional case of *Armillaria* and *Gastrodia*. The ability of the fungus to transport nutrient solutions has been made use of by the flowering plant. As in the case of Leguminosae and their nodules the tables have been

* T. Weevers, Das Vorkommen des Ammoniaks und der Ammonsalze in den Pflanzen. Recueil des Travaux botaniques Néerlandais, XIII, pp. 63–104 (1916).

† W. B. McDougall, On the mycorrhizas of forest trees. American Journ. Bot. I, pp. 51–74 (1914).

‡ L. Rexhausen, Über die Bedeutung der ektotrophen Mykorrhiza für die höheren Pflanzen. Beit. z. Biol. der Pflanzen, XIV, pp. 19–58 (1920).

turned and the "host" has become the aggressor, even attracting the fungus to the embryo. We are short of definite facts—there is a conflicting mass of detail on such an important point as the relation between the endophyte and the soil—and until these are obtained one theory seems as good as another.

It would be indeed strange if the difference between ectotrophic and endotrophic mycorrhiza should resolve itself into a case of the fungus being parasitic on the flowering plant in the former, while in the latter the flowering plant is parasitic on the fungus.

I am indebted to Mr E. H. Ellis for the photomicrographs, with the exception of Figs. 1 and 4, for which I must thank Mr R. J. Tabor.

While the above was in the press an important paper by H. Christoph entitled "Untersuchungen über die mykotrophen Verhältnisse der 'Ericales' und die Keimung von Pirolaceen" appeared in Beih. Bot. Centralbl. XXXVIII, pp. 115–157 (1921). In it the author controverts the results obtained by Rayner concerning the necessity of the root-fungus for seed-germination (cf. p. 48). It should be noted, however, that he has not seen the full description of Dr Rayner's researches, but apparently only an abstract of her preliminary account. Christoph concerned himself with the manner in which the fungus reaches the roots of the Ericaceae, whether from the soil or from the seed coat. His first series of experiments were performed with cuttings. He took both large and small green side shoots from plants of *Calluna vulgaris* both wild and cultivated. These were planted in shallow pots in humus heath soil—the soil in the one pot being sterilized and that in the other not. In both experiments a number of cuttings struck and succeeded in establishing themselves. The roots of the cuttings in unsterilized soil became slightly infected, but no fungus could be found in those growing in sterilized soil. On replanting and transferring the latter cuttings to sandy soil they still remained free from fungal infection and continued in that condition for two and a half years.

Similar experiments with cuttings of *Erica carnea* gave analogous results. Both series succeeded and those planted in sterile black heath soil, and after one and a half years transferred, remained free from fungus infection for two and a half years.

The plants without fungi in their roots were in just as good a condition as those which became infected and Christoph is of the opinion that the fungus is of no assistance to the plants and must be regarded as a harmless parasite.

A second part of the paper deals with germination experi-

ments with these two species. The results of thirteen experiments are summarized, though the complete account is not published.

Different soils were tried, both sterilized and unsterilized. Seeds of *Calluna* and *Erica* were sown in these, some having their coats sterilized, some being used just as they were taken from the capsules. The results were similar in both series of experiments, except that *Erica carnea* germinated only in the absence of light. Germination occurred in all experiments, e.g. sterilized seeds germinated in sterilized soil. Only those seedlings growing in unsterilized soil become infected with fungus whether the seeds are sterilized previously or not: in certain cases seeds which were taken from capsules in which a fungus was very obvious did not give rise to infected seedlings when sown in sterilized soil. The author concludes that infection of the root always comes from the soil and never from the seed coat.

Regarding infection in the capsule, Christoph states that so long as the carpels are still green and the seed white a fungal infection of the tissue can never be observed.

The author succeeded in extracting the fungus from the roots of the plants, but was unable to obtain spores in pure culture and was therefore unable to identify it. That it was probably the appropriate fungus was shown by infecting seedlings of both *Calluna* and *Erica*.

The Ericales are considered to be facultative mycotrophic plants, since specimens growing in normal conditions always have fungus in their roots. In very dry places, however, plants of *Calluna vulgaris* and of *Erica carnea* are often without fungi; and in pot cultures allowed to become dry the fungus soon disappears.

The third portion of the paper deals with the Pyrolaceae. Working with *Pyrola uniflora*, *P. secunda*, *P. minor* and *P. rotundifolia* it was found that the hyphae of the infecting fungi had clamp-connections (and were therefore probably Basidiomycetes). The conclusion reached is that here also no true "symbiosis" exists—infection depends upon many external factors, of which temperature, soil, moisture and aeration are the chief. Coralloid roots are not brought about by infection: there is a special development of the large epidermal cells and these, owing to their function of absorption, are specially suited for fungal development.

In *Monotropa* the fungus possesses no clamp connections.

The author was successful in germinating seeds of *Pyrola rotundifolia* which he chose, as they were the largest of the four species. The best results were obtained from: 1. Strong concentrated soil-extract. 2. Addition of peptone solution. 3. Sowing

on humus from habitat of plant—on sterilized soil there was no germination. 4. Keeping cultures in the dark. 5. Moderate moisture.

It is suggested that the carbon compounds of the highly concentrated soil extract, acting in combination with the peptone, brought about germination by chemical action.

Parallel experiments with peptone solution alone, soil extract alone, and with a mixture of both gave a slight germination in peptone solution, a stronger one in soil extract, but much the best is a mixture of the two.

With regard to the question of infection of the seedling root from the capsule it is obvious that there is great discrepancy between the accounts of Rayner and Christoph, and until the results of one or other worker be confirmed it is not possible to draw from them theoretical conclusions. That cuttings of *Calluna* can strike and come to maturity in sterilized soil without root infection is somewhat unexpected on account of Rayner's clear description of the distribution of the fungus in the plant; in cultivated orchids it is quite likely that after the seedling stage fungal infection is not necessary.

Concerning the germination of *Pyrola rotundifolia* seeds the account is not full enough to draw from it any theoretical conclusions. The fact that the seeds can be brought to germinate by chemical means is not surprising: it is analogous to what has been found by Bernard in *Cattleya*. There was apparently no attempt made to try the effect of the root-fungus on germination.

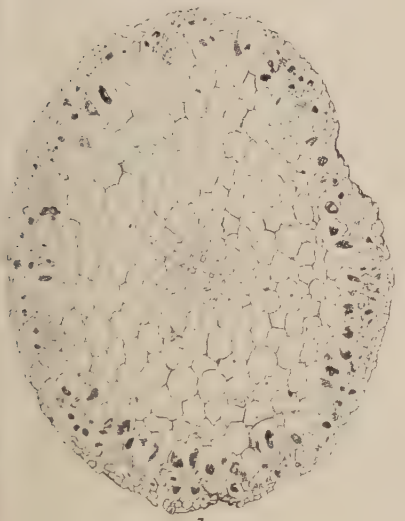
EXPLANATION OF PLATES.

Plate II.

Fig. 1. Transverse section of root of *Habenaria* just above the root tip. The dark masses show where digestion of the fungus is taking place. ×36.
Fig. 2. Seed of *Cymbidium*, stained and mounted whole. The embryo is seen as an oval black patch within the network integument. ×56.
Fig. 3. Longitudinal section of a seed of *Odontoglossum*. The anterior end shows smaller cells, the posterior end larger cells. (The integument has been ruptured in making the preparation.) ×215.
Fig. 4. Fungus from *Odontoglossum* (*Rhizoctonia lanuginosa* Bern.) at the beginning of sclerotium formation. ×36.
Fig. 5. The same more highly magnified showing chains of "spores." ×215.

Plate III.

Fig. 6. Seed of *Odontoglossum* sown seven days on a culture of the fungus: stained and mounted whole. ×56.
Fig. 7. The same more highly magnified. ×215.
Fig. 8. Longitudinal section of a seed of *Odontoglossum* nine days after sowing. The fungus has entered the larger cells at the suspensor end of the seed and formed balls of hyphae. (The integument has been broken in cutting the section, cf. Fig. 6.) ×215.
Fig. 9. Section of protocorm of *Odontoglossum*. The growing point of the stem can be seen at the upper end and the first and second leaves (Section



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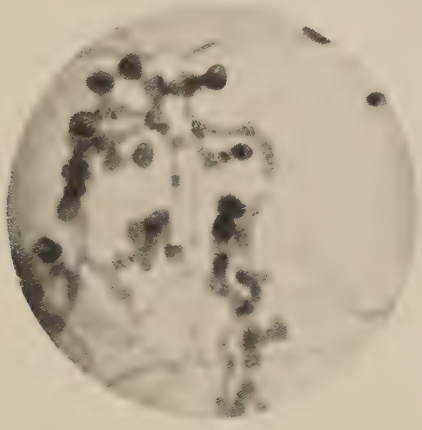

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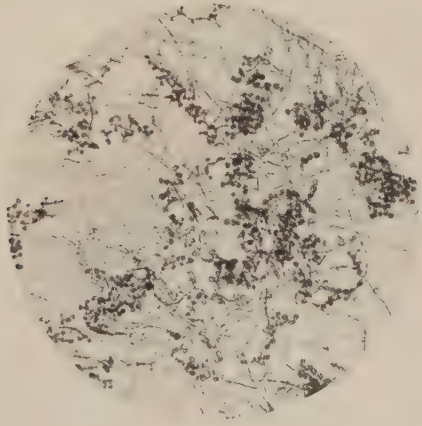

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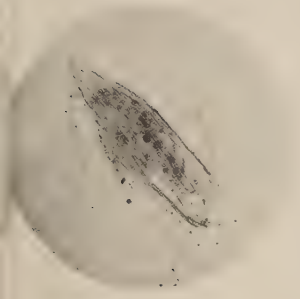

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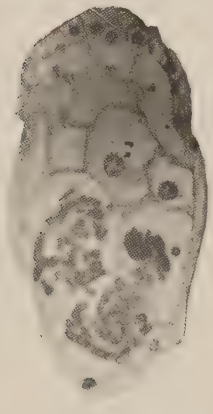

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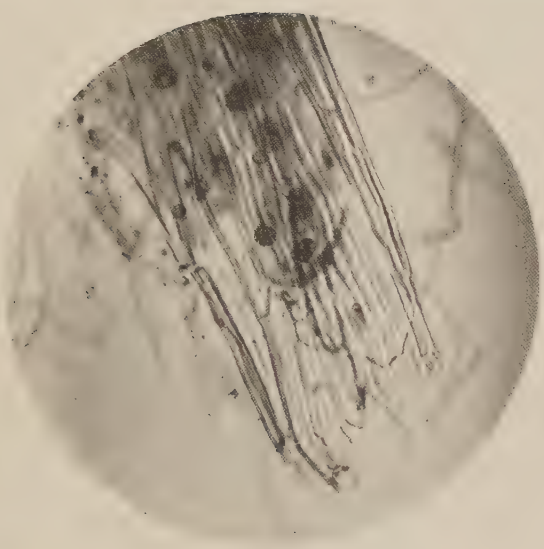

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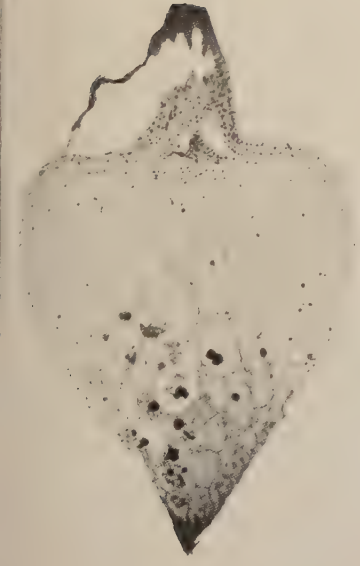

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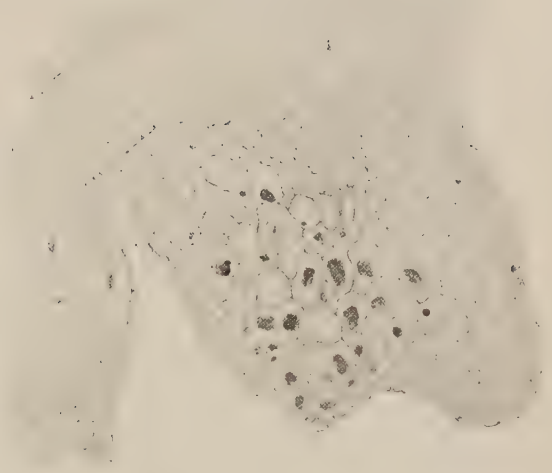

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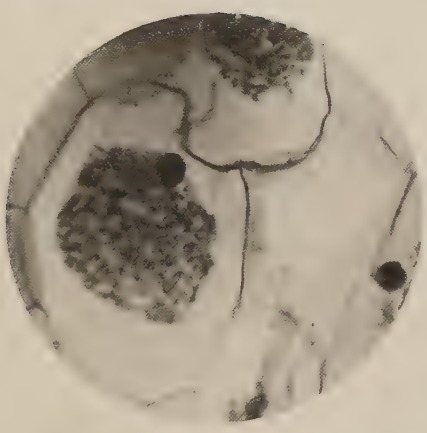

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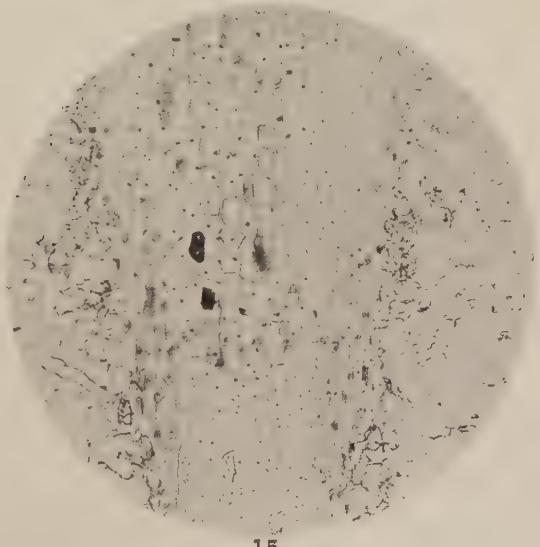

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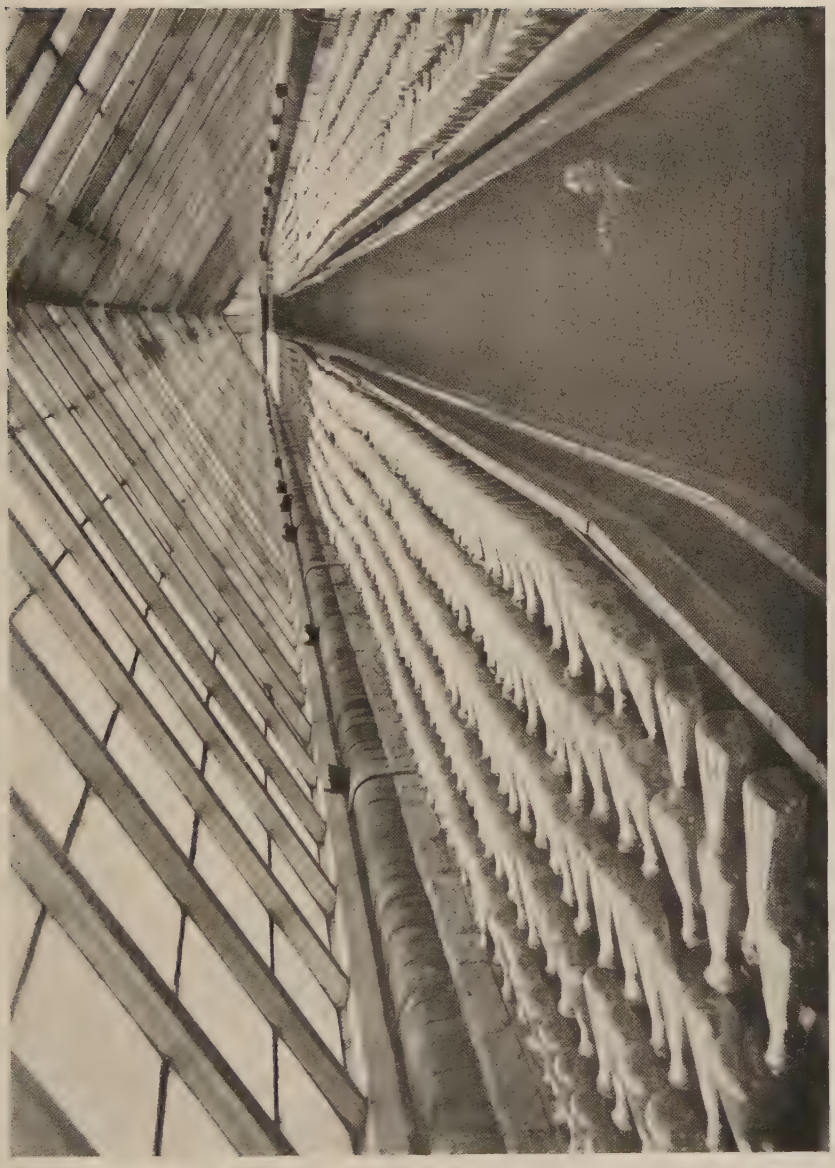

not quite median). The fungus in many of the cells is already digested. × 56.

Fig. 10. Later stage of *Odontoglossum* showing the beginning of the formation of the central stele and root. The stem growing-point is well developed. The fungus in the cells is mostly digested. × 36.

PLATE IV.

Fig. 11. Protocorm of *Vanda* showing the young root absorbing its way out of the side of the protocorm away from the fungal zone. × 18.

Fig. 12. *Odontoglossum* seedling after the formation of the first root. The root is not infected from the protocorm. (The dark patches in the root are raphides.) × 36.

Fig. 13. Cells from fungal zone of Fig. 12 more highly magnified. The fungus is "clumped" (cf. Fig. 8). A fungal hypha is seen passing through the cell-wall. × 215.

Fig. 14. Longitudinal section of the root of *Habenaria* near the tip. Digestion is more prominent in the older (upper) portion of the root. × 18.

Fig. 15. Longitudinal section of an aerial root of *Epidendrum* showing infected cells in the centre and mycelium in the velamen. × 18.

PLATE V.

Odontoglossum house; first stages of seedling raising by the "pure culture" method.

PLATE VI.

Odontoglossum house; seedlings one year old grown by the "pure culture" method.

PLATE VII.

Odontoglossum house; seedlings three and four years old.

MYCORRHIZA IN THE ERICACEAE.

By M. Cheveley Rayner.

There has recently been published a paper by Christoph(1) containing an abridged account of researches carried out by him on the relations between plant and mycorrhizal fungus in the Ericaceae. The species studied were *Calluna vulgaris* and *Erica carnea* and that part of the investigation with which the present critical review deals is concerned with (*a*) the behaviour of "cuttings" of the shoot, and (*b*) seed cultures of the former plant.

With the researches on "cuttings" I do not propose to deal at present as it is hoped that a paper may be ready for publication in the near future detailing the results of my own experiments in the same direction. With regard to the work on seed cultures of *Calluna*, the experimental results recorded by Christoph are so remarkably at variance with those published in 1915(2) and since that time repeatedly confirmed by me, that I welcome the present opportunity of discussing them in some detail.

As a starting-point of my own investigations may be taken the simple observation that seed of *Calluna* germinated on moist filter paper in a germinator yields seedlings which root freely in the seed dishes, the roots showing regular fungal in-

fection of the kind typical to the plant. In such seedlings infection by hyphae from the seed coats can commonly be observed and similar observations have been made on seeds germinating viviparously within the fruit by Ternetz(3) for *Calluna* and by me for *Pernettya mucronata*. Moreover, it is often possible to observe the presence of fine hyphae upon the seed coats of ripe seeds taken from *unopened* fruits, the observation of which may be facilitated by the use of careful methods of maceration. Interovarial infection can be demonstrated in sections of unripe fruits with the aid of a very careful technique, although such demonstration of infection of seeds within the ovary usually involves a relatively large amount of tedious and painstaking work. I am of opinion that extensive infection of the seed coats occurs only at a late stage, and is probably associated with death and desiccation of the tissues composing the fruit-wall and the increased mycelial activity subsequent to this.

In my experience, very careful work and much patience are needed to obtain convincing proofs of the presence of mycelium within the ovary and young fruit. For this reason I do not attach great importance to Christoph's failure to observe it. I have offered elsewhere what I believe to be convincing evidence on this matter (*loc. cit.*).

The technique adopted by me to obtain seeds free from infection is as follows. Seeds, freed from all impurities, are wetted by centrifuging, they are then sterilized by immersion in 1 % mercuric chloride for three minutes and, after repeated rinsings in sterile water, sown on agar media containing sugar and peptone to facilitate the detection of micro organisms if present. In my original experiments, seedlings from such pure cultures were transferred to tubes of broth and bouillon kept at various temperatures, in order to test in the most drastic way possible their freedom from micro-organisms (*loc. cit.*).

Seedlings raised in this way and planted in nutrient agar suitable for their growth do not develop a root system and eventually die; if inoculated at planting from a suitable pure culture of the endophyte *isolated from the ovary or unopened fruit*, they develop normally in every way and the roots show typical infection.

Every link in this chain of events has been demonstrated experimentally and there is no escape from the following conclusions:

(*a*) That under the experimental conditions described development of the *Calluna* seedling is bound up with infection.

(*b*) That such infection takes place regularly from the testa of the seed at, or subsequent to, germination.

As a further result of experimental work I claim also to have shown that infection of the seeds within the fruits takes place as a consequence of the widespread distribution of the endophyte throughout the plant body. The evidence for this need not be discussed here, but it may be pointed out that the production of infected roots by "cuttings" rooted in sterilized sand under aseptic conditions would provide convincing confirmation of the presence of the fungus in the shoot tissues.

To pass to Christoph's work on seed cultures. The behaviour of seeds and seedlings was investigated as follows:

(*a*) *Unsterilized seeds on sterilized soil.*

Seeds were subjected to prolonged soaking in rain water and sown on peat (Torfmulle) sterilized by repeated autoclaving: controls were sown on untreated peat.

After six months it is recorded that the seed sown on sterile peat had produced seedlings 7–11 mm. high with root systems 24 mm. long *in all cases entirely free from fungus infection.* Other cultures of a similar kind gave on unsterilized soil, seedlings with roots infected: on sterilized soil, seedlings equally vigorous with roots which were still entirely free from fungal infection a year after sowing.

With regard to these results it may be pointed out that until my claim of seed coat infection has been disproved, all seedlings raised from unsterilized seed would be assumed liable to infection at germination. In my own researches, I have been careful to use seed from as many different sources as possible, but have never observed a case of non-infection of roots in experimental plants, nor have I ever found a plant growing under natural conditions or under cultivation without mycorrhiza. I do not deny the possibility that such plants may exist; I can only affirm my own experience in this matter. On the other hand, it is not always easy to observe infection in the clean roots of seedlings and in the absence of opportunity to examine the material, it is only possible to assume that the presence of mycelium in the roots of these seedlings has been overlooked by Christoph.

(*b*) *Sterilized seeds on unsterilized soil.*

Seeds were sterilized in various ways: in the later experiments by means of 1 % mercuric chloride. After sterilization they were sown on a suitable soil from a *Calluna* area (Diesenhofenen Erde). These cultures are recorded as giving after six weeks seedlings 5–10 mm. high with roots normally infected. Christoph assumes that these experiments provide conclusive proof that infection by the mycorrhizal fungus takes place *only* from soil.

Clearly this is not the case. All the seeds were sown on peaty soil without controls on sterile media and no proof of any kind is offered that the seeds were adequately sterilized. If the soil used was from a *Calluna* station infection evidently could take place from roots in such soil, as it may do in nature in the case of seedlings germinating near the parent plant.

The view has never been put forward by me that the endophyte is not present in soil or that infection *cannot* take place from this source. On the contrary, it is obvious that the soil of an area occupied by *Calluna* will always contain the fungus. Concerning the distribution of the endophyte in soil generally I have at present no data, nor have I expressed any opinion as to its independent occurrence in nature apart from the *Calluna* plant.

(*c*) *Sterilized seeds in sterilized soil.*

Seeds were sterilized with 1 % mercuric chloride. The soil brought from a *Calluna* area (Diesenhofen) was repeatedly autoclaved at 140° C. It is recorded that at the end of five months the experimental seedlings were well rooted, the roots being entirely free from infection by fungal hyphae. As in the experiments described under (*a*), no proof of seed sterility is offered. Until such proof can be supplied, it is only possible to repeat the criticisms under (*a*).

It is greatly to be desired that Dr Christoph should repeat these experiments providing rigorous proof of seed coat sterility subsequent to sterilization, and that he should then maintain his cultures under aseptic conditions. It is not recorded that any attempt has been made to do this in the case of those described and the possibility of air-borne infection of sterile cultures is ignored. It appears to the writer that just conclusions as to the biological relationships between organisms found growing in close association in nature can only be reached as the result of "pure culture" work which will pass the tests demanded by any competent bacteriologist. Anything less is obviously unsatisfactory and cannot yield conclusive evidence. The following quotation from Christoph's paper shows how far from this ideal were the cultures upon which he bases his conclusions:

"Anfangs machten sich einige Zeiten hindurch Rasen von *Mucor* und *Citromyces* unangenehmen bemerkbar, ohne jedoch Schaden unter den Pflanzen anzustiften. Wie bereits anlässlich die Beschreibung der *Calluna*-Steckling Kultur erwähnt wurde sind diese Pilze nicht imstande die Wurzeln zu infizieren, weshalb ein Nachteil für die Sicherheit des Ergebnisses auch nicht zu befürchten war."

The number of seedlings dealt with is not always mentioned.

When it is, criticism is invited, e.g. ten seedlings in one experiment, eleven seedlings in another. Numbers so low in the case of seeds so small as those of *Calluna* raise grave doubts as to the general conditions of the cultures.

Again, the proof offered by Christoph of the identity of a fungus, isolated by him from clean pieces of *Calluna* root, with the endophyte is unsatisfactory. So far as is possible to judge from the description of morphological characters, the right fungus was isolated from the root although spores were not produced. *Positive proof of identity can only be supplied by inoculation into a pure culture seedling growing under controlled conditions with subsequent production of mycorrhiza.*

The method adopted was to sow *unsterilized* seeds in pots of sterilized soil, and transfer the seedlings so obtained to pots of sterilized soil inoculated with the fungus he had isolated from roots.

According to Christoph the first roots of such seedlings remained sterile, the numerous laterals which developed became typically infected. On my view, such seedlings would always become infected at germination, their establishment as rooted plantlets depending upon this. Even assuming the seed coat to be free from infection by the specific root fungus, the method used by Christoph is obviously incapable of providing the strict proof of identity required.

Attention has already been drawn by me (*loc. cit.* p. 61) to the possibility of replacing the stimulus to development normally provided by the fungus by stimuli of a chemical nature, e.g. by the addition of organic substances to the rooting medium in which seedlings are growing. It is even conceivable that an appropriate organic substance might be present in sterilized peat and so provide an explanation of the discordant experimental results recorded by Christoph. This possibility is now being fully explored.

In conclusion, may I add one word as to the experimental difficulties experienced in work of the kind under discussion? After many years' work I am still far from a complete understanding of the co-ordination shown by plant and endophyte in Ericaceae. There is, for example, a close and, at present, unexplained correlation between germination of the seed and activity of the mycelium on the seed-coat. Again, the presence of the endophyte in the tissues of the shoot and within the unopened fruit makes its isolation theoretically a simple matter; in practice this is difficult, and I am still ignorant of the exact conditions which determine the ability or otherwise of the fungus to grow out from the tissues.

Owing to the extreme delicacy of the balance between seed-

lings and endophyte, the production of "synthetic" seedlings is not a simple operation. The age of the seedling, the suitability or otherwise of the rooting medium, the age of the fungus culture and the nutrient on which the endophyte is cultivated outside the plant are all critical factors, as are also doubtless such formal external conditions as temperature, moisture, and light.

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AN EOCENE MICROTHYRIACEOUS FUNGUS FROM MULL, SCOTLAND.

With Plate VIII.

By W. N. Edwards, B.A., Department of Geology, British Museum.

Well-preserved fossil fungi are of comparatively rare occurrence, and most of those so far described are found in petrified material. Names have certainly frequently been given to spots and markings on leaf impressions, which, however, rarely show any structure and are of very little botanical value. It is therefore of interest to be able to record the discovery in some Tertiary Rocks of Scotland of an unusually well-preserved epiphyllous fungus.

The Eocene interbasaltic beds of Mull contain a varied flora of ferns, conifers and dicotyledons mostly preserved as impressions. In a very few cases the actual leaf cuticles have remained practically unchanged in what has been called a "mummified condition," and by treatment with Schultze's mixture or some other reagent can be cleared and examined microscopically. This method of preservation is familiar to palaeobotanists, who have found the details of stomatal structure and cell outline valuable aids to classification, especially in the case of certain gymnosperms.

The microscopic fungus about to be described was found in the course of examining some linear coniferous leaves scattered on the surface of two slabs of rock in the Starkie Gardner Collection (Specimens V, 14846 and 7). With the object of

studying the leaves themselves, small fragments of the cuticle were detached from the rock and treated with nitric acid and potassium chlorate, followed, after washing, by ammonia. This process removes the carbonaceous matter and leaves a clear brown cuticle which can then be mounted in glycerine, the upper and under epidermis being first separated with needles. Some very small dark spots, which could not be seen before treatment, were then observed with the naked eye on the clear cuticle, and these proved on microscopic examination to be discoid bodies with a radiate structure which at once suggested a small epiphyllous fungus. I showed the specimens to my colleague, Mr J. Ramsbottom, who expressed the opinion that they probably belonged to the Microthyriaceae. In the subsequent study of this fungus I have continually received much help from Mr Ramsbottom and I am greatly indebted to him for his advice and assistance.

FIG. 1. Slab of rock with *Pityophyllum* sp., a coniferous leaf attacked by *Phragmothyrites*. Eocene, Mull. Brit. Mus. (N.H.), Geol. Dept. no. V. 14846. Nat. size.

Description of the material. The discoid bodies, which are regarded as the ascostromata (or "thyriothecia") of a Microthyriaceous fungus, occur singly, or rarely in concrescent pairs, on the upper surface of the leaf, and in some preparations are scattered over it in considerable numbers (cf. Pl. VIII, fig. 1). They are usually practically circular, and the largest specimen

is about 165 μ in diameter. They have a regularly radiate structure and the margin is entire, or very slightly crenate, but never fimbriate. None of the specimens show a definite ostiole, but this may be due to immaturity, while on the other hand there is an appearance in some ascostromata of an irregular dehiscence such as occurs in some recent members of the family, e.g. *Asterina*, but appearances in fossils such as this are liable to be deceptive, and might be due to post-mortem or post-fossilization changes. There is no mycelium on the surface of the leaf, but stigmocysts (Pl. VIII, figs. 5 and 6) are abundant, and all stages of growth are to be found between them and the largest of the ascostromata. The stigmocysts (unicellular capitate hyphopodia) are circular and deeply crenulate, about 10–12 μ in diameter, and the clear central spot is usually distinctly seen.

No asci have so far been found, but Pl. VIII, fig. 7 shows a large 5-celled spore (? ascospore), 43 μ in length and 25 μ in breadth, which appears to be sending out delicate hyphae at each end. Another slide shows a similar spore, rather shrunken, with apparently only four cells. It seems quite probable that these spores belong to the same species as the ascostromata, though of course one cannot be absolutely certain. At any rate there is no other recognisable fungus on the leaves to which they might belong. There are a few detached fragments of hyphae and some spore-like bodies which may perhaps be mentioned here, but which may not even be of fungal nature.

The reference of a fossil fungus to its exact systematic position is not an easy matter, even when the material is so well preserved as in the present case. There are certain characters which are used in the classification of recent fungi which cannot be observed in a fossil, e.g. the colour of the spores, and moreover dissociated objects cannot always be proved absolutely to belong to the same species. In this instance one can at least feel fairly certain that the fossil is to be placed in the Microthyriaceae, though the exact generic reference is more difficult.

The Microthyriaceae and other "asterinoid" fungi have received considerable attention of late years, and their classification and relationships have been critically studied and revised by von Höhnel, Theissen, Arnaud and others. Desmazières' genus *Microthyrium* (1841) was made the type of the family Microthyriaceae by Saccardo in 1883, and this family subsequently became the dumping ground for many heterogeneous forms which have since been excluded, while on the other hand detailed study has resulted in the separation of many new genera. The classification of Theissen (1913, 1 and 1913, 2) forms the basis of our present knowledge. He groups together

the Microthyriaceae, the Hemisphaeriaceae and the Trichopeltaceae in a new order, the Hemisphaeriales, which are all superficial, and are thus sharply marked off from the Dothideales, in which the ascostromata are developed beneath the cuticle. For the hemisphaerical fruiting bodies he adopts von Höhnel's term thyriothecium. The distinctive characters of the Microthyriaceae, with which we are particularly concerned here, are the radiate (very rarely linear) dimidiate thyriothecia, on the "inverse" method of whose development von Höhnel and Theissen lay great stress. They regard the thyriothecium as corresponding to the basal half of the spherical body such as occurs in related families (e.g. Perisporiaceae) which has become inverted against the leaf surface. The family is subdivided according to the presence or absence of a free mycelium, the number of cells and colour of the ascospores, the presence or absence of paraphyses, and so on. This classification is adopted with slight modifications by E. M. Doidge (1920) where a résumé of the general characteristics of the group will be found.

Arnaud (1918) proposes a somewhat different classification based on that of Spegazzini, and uses the term Microthyriaceae in a rather wide sense, while excluding, however, certain genera such as *Amazonia*. Arnaud gives the pycnidial forms a special name (Microthyriopsidaceae); the pycnidia resemble the thyriothecia as a general rule, and therefore we cannot be quite sure which we are dealing with in the present case. Certain spore-like bodies on the leaf cuticle might perhaps be conidia.

The form of the thyriothecia in the fossil is very similar to that of *Microthyrium* itself, while in this and allied genera the mycelium is absent or evanescent. Presuming the ascospore to belong to the same species as the fruiting bodies, a relationship is indicated to the genus *Phragmothyrium* of von Höhnel (1912, p. 347) which was instituted to include "*Microthyrium* species with more than 2-celled spores." *Amazonia* Theiss. is also phragmosporic (5-celled) but has a persistent mycelium and rather different thyriothecia with fimbriate margins. It is therefore suggested that the name *Phragmothyrites* be used for fossil forms belonging to the Microthyriaceae, the exact position of which is uncertain, but which appear to be most closely related to *Phragmothyrium* as defined by von Höhnel. The Mull specimen may be described as *Phragmothyrites eocaenica* n.sp. Thyriothecia circular, radiate, with entire margin, scattered singly (rarely concrescent) on the leaf surface; stigmocysts circular and deeply crenulate; ascospores (?) 5-celled; mycelium ? absent or evanescent. Occurring on coniferous leaves (*Pityophyllum* sp.) in beds of Lower Eocene age, Mull, Scotland.

I have only succeeded in finding a few other references to

fossil fungi belonging to this family. *Microthyrites disodilis* Pampaloni (1902, 1, p. 251; 1902, 2, p. 127, Pl. XI, fig. 1) occurs in the disodil of Melilli, Sicily, probably of Middle Miocene age. From Pampaloni's description, an affinity with the Microthyriaceae is quite possible, but the illustration leaves much to be desired. The material is said to consist of simple, scattered, shield-shaped perithecia, composed of polygonal concentric cells, and there is no reference to spores or mycelium. Altogether the record seems rather doubtful.

Engelhardt and Kinkelin (1908, p. 185) record a few leaf-fungi from the Upper Pliocene of Klärbecken near Frankfurt-am-Main, and among them one which they refer with a query to a living species, *Asterina Ilicis* Ell., on leaves of *Ilex*. They describe circular thyriothecia (sometimes concrescent), 80–90 μ in diameter, with a crenate margin and a central ostiole when mature. Their drawing certainly closely resembles a Microthyriaceous fruit-body, and they state that an affinity to *Asterina* is indicated by the presence of a free mycelium ("Luftmyzel"), which however is not figured. They further record similar fruit-bodies on *Buxus* leaves, but smaller, with an entire margin, and without any free mycelium. Kräusel (1920, p. 338, text-fig. 7, p. 353) describes some similar bodies from the Miocene of Silesia, about 70 μ in diameter, found associated with *Sequoia langsdorfii* leaves, and apparently connected with hyphae. They are regarded as probably belonging to the Microthyriaceae. In neither of these cases were any spores found.

"Hyphae and haustoria of an *Asterina*-like fungus" occur on the cuticle of *Sequoia langsdorfii* from Tertiary beds (exact age unknown) of Ellesmere Land, lat. 77° N., and are described and figured by Nathorst (1915). The resemblance to the mycelium and stigmopodia of *Asterina* and other allied genera is certainly very striking. It is interesting to note that this fungus was discovered in the same way as *Phragmothyrites eocaenica* and the fungi described by Kräusel, by chemical treatment of a coniferous cuticle, and the preservation of the mycelium suggests that had *P. eocaenica* possessed a persistent mycelium it would also have been preserved.

The identification of the host plant presents some difficulties, but it is best referred to provisionally as *Pityophyllum* sp. (a name used for fossil coniferous leaves of uncertain affinity). A somewhat similar conifer, *Podocarpites campbelli* (Gard.), is a common fossil at Mull, but the leaves are usually larger and more acuminate. The scattered leaves of the present specimen, as shown in Text-fig. 1, may be compared with a figure of *Podocarpus suessionensis* Wat., given by Crié (1878, Pl. VII, fig. 32) of a specimen from the Eocene of Sarthe, but here again

it should be noted that the Mull leaves are not so acuminate. The identification even of leafy coniferous twigs is not easy, so that the attribution of detached leaves must be very uncertain. In the present instance, however, the cuticle preparations show to some extent the structure of the stomata, and these were kindly examined for me by Miss H. Bandulska, who made a series of comparative measurements. She believes that the stomata were of a type found in *Sequoia sempervirens* and some species of *Araucaria* and *Podocarpus*, the greatest resemblance being to those of *Podocarpus melangianus*. The host plant of *Phragmothyrites eocaenica* may therefore possibly be a *Podocarpus*. The question of its stomatal structure and identity will be dealt with more fully in another place. No other leaves from Mull yield cuticles, with the exception of *Ginkgo adiantoides* Ung. on which no traces of fungi have been found.

The presence of this epiphyllous fungus would seem to indicate fairly moist conditions of growth. The living Microthyriaceae are mainly tropical, but rainfall rather than temperature would appear to be the important factor influencing distribution. Arnaud (1918, p. 31, etc.) asserts that "asterinoid" fungi are confined to parts of the globe with more than one metre of rainfall per annum. Prof. A. C. Seward and Mr R. E. Holttum, who kindly allowed me access to a forthcoming paper on the Mull fossil plants, consider that the flora indicates a temperate climate, but warmer than that of the present day in the same latitude, and they speak of the possible presence of evergreen shrubs as another indication of a warm, fairly moist climate. They see no reason to modify Gardner's opinion that the beds are of Lower Eocene age.

In conclusion we may note that very few living species of Microthyriaceae have been recorded from Great Britain.

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EXPLANATION OF PLATE VIII.

All the specimens are in the Geological Department, British Museum (Natural History). The photographs are by Mr F. W. Edwards.

Fig. 1. *Phragmothyrites eocaenica* sp. n. Group of thyriothecia. ×80. Slide V. 14847*a*.
Fig. 2. *Phragmothyrites eocaenica* sp. n. A single thyriothecium. ×380 (the largest observed). Slide V. 14847*a*.
Fig. 3. *Phragmothyrites eocaenica* sp. n. Another thyriothecium. ×380. Slide V. 14847*a*.
Fig. 4. *Phragmothyrites eocaenica* sp. n. Two thyriothecia at an earlier stage of development. ×380. Slide V. 14847*a*.
Fig. 5. *Phragmothyrites eocaenica* sp. n. A stigmocyst. ×540. Slide V. 14846*b*.
Fig. 6. *Phragmothyrites eocaenica* sp. n. Group of stigmocysts beginning to grow. ×540. Slide V. 14846*a*
Fig. 7. Presumed ascospore of *Phragmothyrites eocaenica* sp. n. ×540. Note the delicate hyphae at each end. Slide V. 14846*b*.

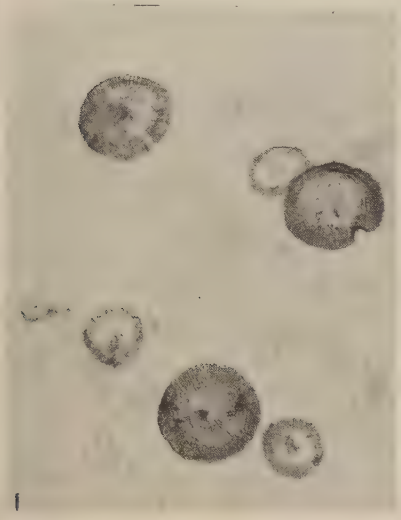
A SINGULAR CORDYCEPS FROM STEPHEN ISLAND, NEW ZEALAND.

By G. H. Cunningham, Wellington, N.Z.

At the north-west extremity of Cook Strait, about three miles from D'Urville Island, the nearest land, lies Stephen Island, a small area one and a quarter miles in length and rising to a height of 900 feet above sea level. The island is for the most part open tussock country with, in the more sheltered localities, a few isolated patches of wind-swept forest.

Although only 370 acres in extent Stephen Island rejoices in the possession of a somewhat unique fauna. Here are found the tuatara, *Sphenodon punctatus* Gray, which occurs in thousands and appears to be slowly increasing in number; *Deinacrida rugosa* Buller, a huge *weta*, found in only one other locality; a Discoglossid frog, *Liopelma hamiltoni* McCulloch, a recently discovered species confined to this island, where its habitat appears to be the crevices under large boulders; and a now extinct wren, *Traversia lyallii* Roths.

With the single exception of the *Cordyceps* described below, the flora possesses no peculiar features, as there are no endemic species.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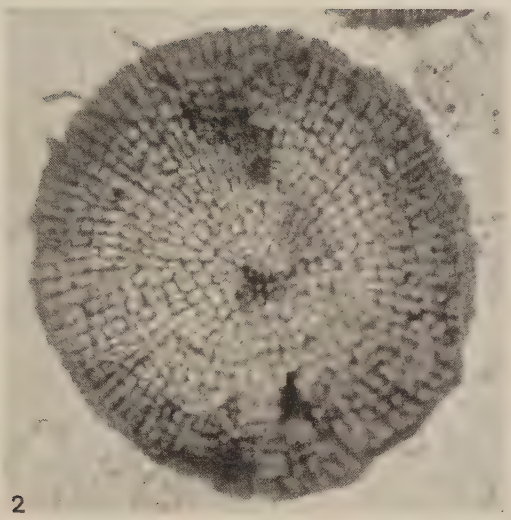
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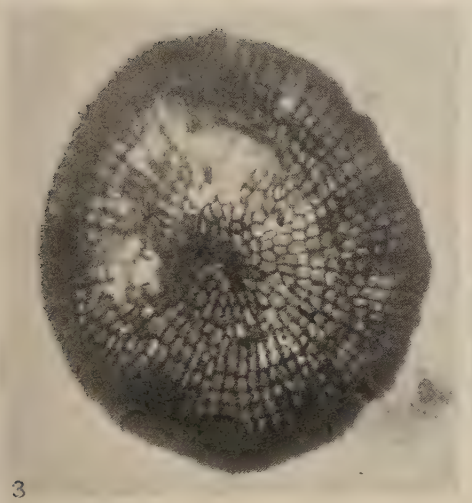
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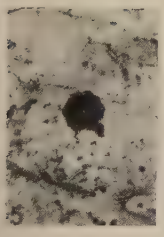
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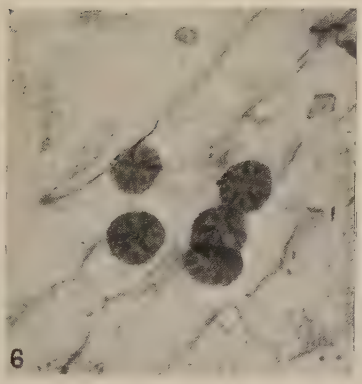
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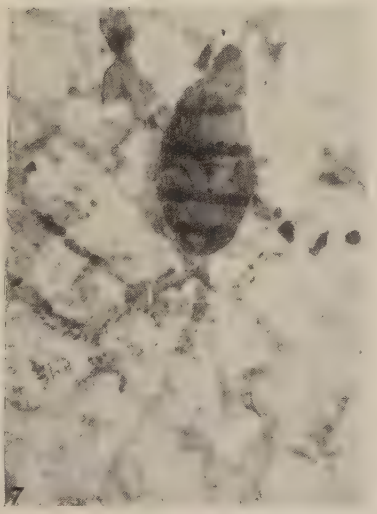
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FIG. 1.

FIG. 2.

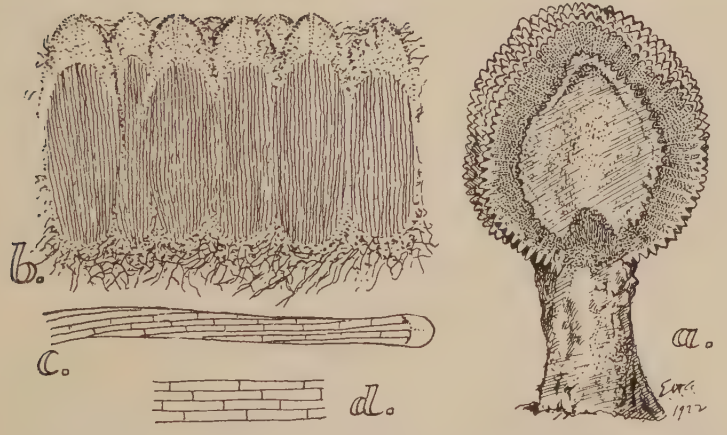

FIG. 3.

Fig. 1. Photograph of *Cordyceps Kirkii* sp.nov. showing gregarious stromata. About twice nat. size.

Fig. 2. Imago of *Deinacrida rugosa* Buller, female specimen. Nat. size.

Fig. 3, *a*. Section through fertile portion of stroma, showing arrangement of perithecia. × 6 diam.

b. Section showing superficial perithecia. Note thick apices of perithecia. × 30 diam.

c. Ascus showing capitate apex.

d. Secondary spores. × 1000.

Photographs by E. Bruce Levy. Drawings by E. H. Atkinson.

The *Cordyceps* specimens referred to were found lying on the ground under stones by Professor H. B. Kirk whilst searching for *Liopelma hamiltoni* McCulloch.

This adds another species to the *Cordyceps* of New Zealand and brings the total up to six, of which no less than five are endemic. The others, together with an account of their hosts, have been discussed by the writer in a former paper published in the Transactions of the N.Z. Institute, LIII, 372 (1921).

I am indebted to Mr W. R. B. Oliver, of the Dominion Museum, Wellington, N.Z., for particulars regarding Stephen Island and its fauna and flora.

Cordyceps Kirkii sp.nov. (Illus.).

Conidial phase accompanying the perithecial, covering surface of host with a dense weft of mycelium, dingy cream, pruinose; conidia hyaline, elliptical, 3–6 × 1–1·5 μ.

Stromata gregarious, growing from intersegmental membranes of the body, and from knee joints, bases of antennae, eyes, and on femurs, stipitate, short, up to 6 mm. long; stem up to 4 mm. long, 1 mm. thick, dingy cream; fertile portion irregularly globose, ovate, or frequently angular, sometimes longitudinally grooved, 1·5–2 × 1·5 mm. diam., pallid brown.

Perithecia superficial, elliptical or elongate-oblong, obtuse, densely packed around a sterile central axis, pallid brown, 700–800 × 150–170 μ, apex thickened up to 120 μ, walls 20–25 μ thick. Asci hyaline, narrowly cylindrical, tapering from apex to base, terminating in a short clavate pedicel, not constricted below capitate apex, 165–210 × 5–6 μ. Spores in spirally twisted fascicles in asci, filiform, same thickness throughout, multiseptate, 80–120 × 1–1·5 μ, secondary spores not readily separable in asci, 6 × 1–1·5 μ.

HOST: Male and female imagines of *Deinacrida rugosa* Buller. Stephen Island, Cook Strait, New Zealand. H. B. Kirk. Jan. 1922.

I have named this species in honour of the collector, Prof. H. B. Kirk, Victoria University College, Wellington, N.Z.

NOTE ON THE HOST. By J. G. Myers.

Deinacrida rugosa Buller*.

This is one of the largest New Zealand species of the interesting Orthopterous family STENOPELMATIDAE, which is well represented in this country by more than thirty species distributed among twelve genera, and all characterised among other peculiarities by the complete absence of wings or elytra.

* Trans. N.Z. Inst. III, 36, 1871.

Under the Maori name of *weta*, and the extremely incorrect titles of "scorpion" or "scorpena," one or other of the commoner species is a familiar object to most people. The species under discussion belongs to an endemic genus. The type is said to have been discovered in an underground burrow at Wanganui; but the species is not now known to me to occur at any locality on the mainland. The two affected specimens, a female with numerous stromata, and a male, were taken under stones by Prof. H. B. Kirk at Stephen Island in Cook Strait where these huge *wetas* are still fairly common and form, in spite of their heavy armature of spines and plates, a portion of the food of the tuatara, *Sphenodon punctatus* Gray. The insect also occurs on Mana Island, and may possibly frequent other islets in Cook Strait.

Cordyceps Kirkii sp.nov.

Statuo conidiale cum statuo peritheciale, superficiem hospitis storea densa mycelii contegente, ravo-pallido-flavo, pruinoso; conidiis hyalinis, ellipticis, 3–6 × 1–1·5 μ.

Stromatibus congregatis, ex membranis intersegmentalibus corporis, et ex genibus, basibus antennarum et oculorum et in femoribus crescentibus; stipitatis, brevibus, ad 6 mm. longis. Stipite ad 4 mm. longo, 1 mm. crasso, ravo-pallido-flavo. Parte fertile inaequaliter globosa, ovata vel saepe angulifera, aliquando in longitudinem striata, 1·5–2 × 1·5 mm. crassa, pallido-brunnea.

Peritheciis externis, ellipticis vel elongato-oblongis, obtusis, dense confertis, pallido-brunneis, 700–800 × 150–170 μ; apice crasso ad 120 μ, muris crassis 20–25 μ. Ascis hyalinis, angusto-cylindraceis, pedicello breve clavato terminatis, infra apicem capitatam non constricto, 165–210 × 5–6 μ. Sporidiis in fasciculis tortuosis in ascibus, filiformibus, cylindraceis, multiseptatis, 80–120 × 1–1·5 μ; sporidiis secundariis non distinguendis in ascibus, 6 × 1–1·5 μ.

Hab.: in imaginibus *Deinacridae rugosae* Buller (Orthoptera). Stephen Island, Cook Strait, Nov. Zeal. H. B. Kirk. Jan. 1922.

THE STRUCTURE AND AFFINITIES OF LEUCONOSTOC MESENTEROIDES (CIENKOWSKY) VAN TIEGHEM.

By W. B. Crow, M.Sc., F.L.S., University College of South Wales and Monmouthshire.

The earliest records of bacteria of the type now known as *Leuconostoc* are of their occurrence as gelatinous masses in the vats containing sugar solutions in beet-sugar factories. These growths, which have been called "gomme du sucrerie" and "frog-spawn," were at first regarded as non-living transformation products of the cytoplasm of the beet itself, but their power of reproduction soon showed them to consist of living organisms. In 1878 Cienkowsky(2) described their microscopic appearance, gave them the name *Ascococcus mesenteroides* and placed them in the Bacteria near Cohn's *Ascococcus Billrothi* (now considered a species of *Micrococcus*(11)). He believed the organism to be very polymorphic and to exist in the cell-forms *Micrococcus, Torula, Bacterium, Bacillus* and *Vibrio*. In the same year van Tieghem(10) summarised earlier observations, examined Cienkowsky's material and also isolated the organism from fragments of dates and carrots. He found that many of the cell-forms noted by Cienkowsky were those of other organisms admixed and that the so-called frog-spawn itself was due to a single cell-type, a coccus occurring in chains or more often in groups of two. Van Tieghem also described the occurrence and structure of spores. In 1892 Liesenberg and Zopf(8) found that the organisms of European beet-sugar factories and those of Javanese cane-sugar works were identical in their morphology and had very similar physiological characters although they could be distinguished by slight differences in some of the latter. They grew both varieties in the absence of glucose and sucrose and found that under such conditions the colonies assume an entirely new form, lacking the gelatinous features of the original type. They failed to find any spores.

Very few researches on *Leuconostoc* have appeared in more recent years. The frog-spawn trouble in sugar-works is now, owing to new methods of procedure, much rarer, and where it occurs certain mucilage forming rod-bacteria are generally the cause, no doubt owing to the different conditions prevailing.

From the above-mentioned investigations, the main features of the organisation of *Leuconostoc mesenteroides* are well known, but in the present account attention may be drawn more particularly to certain characters which have a bearing upon the affinities of the plant and which previously have been overlooked. Only the typical species *Leuconostoc mesenteroides* (Cienk.) van Tieghem was studied. No doubt a number of allied species exist(6).

When grown in liquid media containing sucrose the colonies assume the form of rounded, slightly elongated, translucent, white masses, very variable in size but often over 1 cm. in length and 1·5 to 2 c.c. in volume. It is stated that under special conditions the individual masses may attain a much greater size than this, and may even occupy volumes of several hundred c.c. The colonies normally show a characteristic deeply folded or cerebriform surface which gives the plant its specific name. In cultures on some solid media (e.g. beet) they retain this character, but on others (e.g. various agars) this is less obvious and may be absent, the colonies tending to an amorphous form, especially on media which restrict the production of mucilage. The colonies of the sheathless form obtained by Liesenberg and Zopf are of course amorphous. Macroscopically the normal colonies can be distinguished clearly from those of certain rod-bacteria of similar mode of life and which form the so-called rice-grain of sugar-works.

The growth of these colonies is often extremely rapid. Under favourable circumstances a volume of forty-nine hectolitres of 10 % sugar solution was filled in the course of twenty-four hours with these spawn-like masses(4). Of course the great bulk of the organism depends on the mucilage and actual average measurements show this, in 10 % sugar solution, to occupy at least one hundred times the volumes of the protoplasts themselves. The same result is obtained if we compare the rate of growth of the colonies on media containing glucose with that on sugar-free media.

Reproduction of the colonies of *Leuconostoc* takes place very largely by vegetative breaking. The development of the colony from a single cell has been described by van Tieghem and by Liesenberg and Zopf. According to these authors the cell surrounds itself by a mucilage capsule and divides to form a filament. The capsule eventually gives place to a tubercular mass of numerous capsules so that a section of the thallus has a pseudoparenchymatous appearance. I find that this is well seen in preparations made with ordinary bacterial capsule stains (Friedlander, Welch). According to van Tieghem this segmentation of the capsules is due to the constriction of the

sheath of the original filament which becomes twisted and intertwined to form the colony.

The cells are generally all alike, being spherical and only 0·8–1·2 μ in diameter. The sheath in well-developed specimens is from 10–20 μ wide but may be less or not developed at all in which case we are dealing with the form *nuda* of Liesenberg and Zopf. I have not seen the large elongated cells as figured

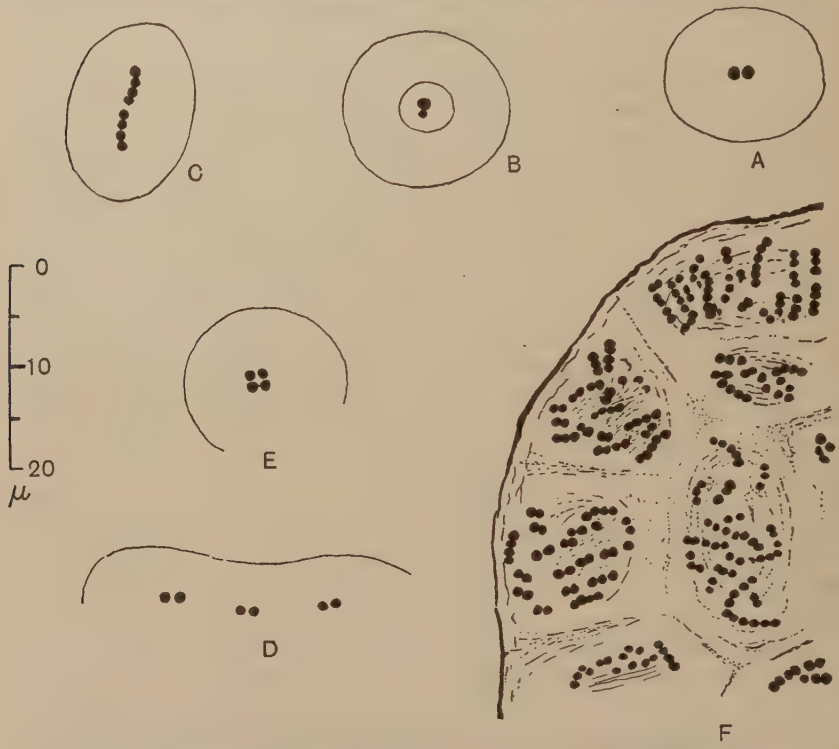

FIG. 1. A–E. Capsules detached from young colony. A. Typical form. B. Form with stratified membrane showing difference in size of cells. C and D. Forms showing filamentous tendency. E. Form showing cell-division in two planes at right-angles. F. Portion of section of colony showing capsules forming pseudoparenchymatous structure.

by Orla-Jensen(6) in his *Betacoccus bovis* but some strains included by him in this species may not be identical with *Leuconostoc mesenteroides*. On the other hand we may sometimes find one of a pair or one cell in a filament differing appreciably in size from the others. Such cells at first suggest arthrospores, but an examination of their behaviour towards stains shows them to be, in their reactions, quite normal cells. The latter

fact disposes of the suggestion that they might represent heterocysts such as are met with in the group of the Cyanophyceae. Whilst the structural characters of the cell-wall in spores and heterocysts and especially the pore and polar granule of the latter would be almost impossible to detect in such small cells as those of *Leuconostoc*, yet it must be remembered, that both the spores and heterocysts of Cyanophyceae have very definite staining reactions which distinguish them from vegetative cells.

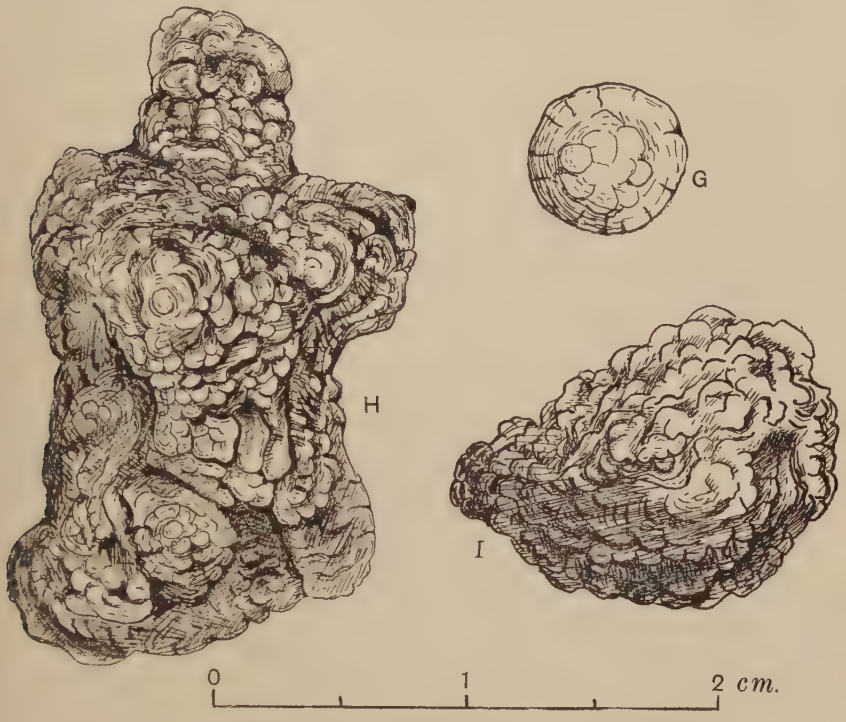

Fig. 2. G. Surface view of colony grown on 10 % sucrose-agar. H and I. Surface view of colonies grown in sucrose solution.

Cell-division generally takes place in one direction only so that the cells form short filaments which, however, seldom reach more than eight cells in length before breaking up, and generally there is a considerable amount of mucilage produced between the successive divisions so that the cells appear in groups of two. Occasionally (or fairly frequently in the form *nuda*) tablets consisting of four cells are seen. This deviation from the normal method of division cannot be regarded as pathological as it occurs in healthy, rapidly growing cultures. As this is the case

such abnormalities may represent a previous phase in the phylogeny of the organism and thus tend to show *Leuconostoc* to be derived from forms, the cells of which divided in more than one direction. Certainly their appearance in an organism derived from typical filamentous ancestors would be difficult to account for.

With regard to the cell contents the extremely small size of the protoplasts is again an obstacle to their investigation. Many strains of *Leuconostoc*, if not all, are gram-negative(11). Beyond this it is only possible to state that neither starch nor glycogen have been detected by the iodine reaction, nor do the ordinary fat reagents give positive results.

The mucilage envelope therefore appears to represent the only material comparable with the solid metabolites seen in so many algae and fungi, and being produced directly from the cell cannot be considered as essentially different in morphological nature from these products. The membrane only develops when the organism is growing in media containing the sugars, sucrose or glucose. As the organism contains the enzyme invertin which decomposes sucrose into glucose it would seem probable that the latter is always the immediate source of the mucilage formation. In the fact that its envelope production is dependent upon a copious supply of hexoses, *Leuconostoc mesenteroides* differs very remarkably from the mucilage-forming algae. But this difference cannot be considered as of importance in relation to the systematic position of the organism since colourless representatives are met with in many algal groups and the situation with regard to mucilage production is the same in *Leuconostoc* as in many algae. In the Cyanophyceae, for instance, although the formation of envelopes is independent of the presence of sugars in the external medium this is because the organisms are autotrophic and in fact the formation of reducing sugars as an early stage in photosynthesis within the cells of many Cyanophyceae has been demonstrated by Gardner(5).

But from a systematic point of view the constitution of the membrane is more important than its original source, since its microchemical structure will depend upon the specific properties of the protoplasm of the organism. Like the cell-wall of the majority of organisms the envelope of *Leuconostoc* is not composed of a single chemical substance(7). This is shown by the work of Scheibler(7, 10) who boiled the gelatinous mass in calcium hydroxide solution and found only a small portion was dissolved. From the extract he obtained dextran which he therefore considered as one of the constituents of the membrane. But as Lafar(7) points out, this substance may be merely a

product of hydrolysis of the constituents. According to Benecke(1) the chief substance is formed by the coming together of several molecules of glucose and the loss of water. In its solubility in strong acids and alkalis the membrane shows a difference in constitution from that of many algae. An investigation of the microchemical reactions of the membrane gave the following results.

(*a*) Cellulose and schizophycose are absent. This is shown by tests with zinc chloriodide, iodosulphuric acid and the calcium chloride reagent of Mangin(9) and the insolubility in cuprammonia solution.

(*b*) Proteins and amino-compounds are absent. Negative results were given by the xanthoproteic reaction, by Millon's reagent and by haematoxylin, etc.(1).

(*c*) Pectins are absent. Observations were made with ruthenium red, safranin and methylene blue, all of which give characteristic reactions with pectic substances if neutral or slightly alkaline material be used(9). Control reactions with *Nostoc* and *Microcystis*, two algae having well-developed envelopes superficially similar to those of *Leuconostoc*, stained red with ruthenium red and, with safranin and methylene blue, gave bright orange and violet coloration respectively. On the other hand the material of *Leuconostoc* did not fix ruthenium and gave rose-red and blue colorations with safranin and methylene blue respectively.

(*d*) The mucilage of *Leuconostoc* has several of the reactions of callose, viz. insolubility in cuprammonia solution, staining reaction with anilin blue, corallin soda, negative reaction with zinc chloriodide and iodine. Unlike callose it does not stain with haematoxylin, is insoluble in dilute alkalis and is optically active.

The envelope is the most striking feature in the morphology of *Leuconostoc mesenteroides*. Structures of comparable form are met with in the Chroococcaceae and the Nostocaceae among the Cyanophyceae and in the Tetrasporales and Heterocapsales among the Isokontae and Heterokontae respectively. Many Cyanophyceae are partially saprophytic and that holosaprophytic members of the group might exist has long been suspected. It is now recognised that palmelloid types have developed independently along various lines of evolution. In *Leuconostoc* as in many other capsulated organisms, the envelope is not always present (f. *nuda*) and we have already referred to the variability in external form of the colonies. The mere possession of the envelope is, therefore, by itself, no criterion of affinity. Moreover, those algal envelopes which approach most closely in external form to that of *Leuconostoc* differ from the

latter in morphological construction. The envelope can be readily separated from the protoplasts, whilst in the Cyanophyceae violent plasmolysis is necessary to effect this. The breaking of the membrane into concentric layers is also a feature in which *Leuconostoc* differs from the Nostocaceae and the majority of other algae. Unlike the higher Cyanophyceae *Leuconostoc* possesses no individual cell-sheath. In this, as in its occasional cell divisions in two planes, *Leuconostoc* approaches the Chroococcaceae more closely than the Nostocaceae. On the other hand the chemical constitution of the envelope is not that of any of the Cyanophyceae, nor of the Tetrasporales or Heterocapsales. The chemical nature of the envelope is undoubtedly an important systematic character, being not only of specific value, since observations on *Leuconostoc mesenteroides* itself show the actual constitution of the envelope to be more constant than its form or degree of development, but also of much higher taxonomic importance in view of the fact that the nature of the membrane substance and of metabolites in general is distinctive in the wider groups (orders, classes) of Thallophyta.

In their report in 1920 on the classification of the bacteria a committee of the American Society of Bacteriologists(11) place the genus *Leuconostoc* in the tribe Streptococceae in the family Coccaceae. According to Orla-Jensen(6) *Leuconostoc*, which as already mentioned he includes in his genus *Betacoccus*, is to be placed in the lactic acid bacteria which embraces, besides many Coccaceae, a number of rod-forms.

Leuconostoc mesenteroides has often been associated with the genus *Streptococcus* and by some writers is included in the latter. The Gram-reaction may perhaps be a distinguishing feature, although the precise systematic value of this character is hard to estimate. It is not absolutely constant for given species amongst the Coccaceae. It might be suggested that the Gram-reaction in the cells of *Leuconostoc* would frequently be hindered by the presence of the secreted mucilage. But some Nostocaceae possessing equally developed envelopes on staining for comparison with *Leuconostoc* show the typical positive reaction. Incidentally it may be mentioned that the species of Cyanophyceae are very variable with respect to the Gram-reaction so that it has no importance as a group character.

The majority of species of *Streptococcus* are parasites, but there are considerable biochemical similarities between the two genera as has been shown by Orla-Jensen(6). The latter investigator has also shown that *Streptococcus* and, in fact, all the bacteria falling in his group of lactic acid bacteria produce capsules during the early stage of development of the colony. On the other hand *Leuconostoc*, in its sheathless form is quite

isomorphous with *Streptococcus*. There is thus no fast morphological distinction between the two genera, but they can be easily distinguished by the fact that the dominant phase in the life-history is different in the two cases.

The obvious affinity of *Leuconostoc* with *Streptococcus* does not enable one to connect the genus with autotrophic forms. In fact many of the species of *Streptococcus* appear to be more advanced both in their morphology and biochemistry. The parasitic habit of *Streptococcus* has already been referred to. The genus *Diplococcus*, which resembles *Leuconostoc* in its paired or sometimes seriate cells and in its frequent formation of capsules, is even more specialised chemically, "growing poorly or not at all on artificial media"(11). Morphological complexity is seen in the development of long chains of cells in some species of *Streptococcus* whilst the special larger cells, already referred to in *Leuconostoc*, are even more conspicuous here, although their nature does not appear to have been studied.

The envelope of *Leuconostoc* has already been noted as staining with the stains used for demonstrating those of bacteria. It thus reacts, on the methods of Friedlander and of Welch, in the same way as the capsule of *Diplococcus lanceolatus*. We have little information concerning the capsules of bacteria in general. The observations of Bräutigam show the gelatinose of *Micrococcus gelatinosus* to be similar to, if not identical with, the chief constituent of the envelope of *Leuconostoc*. On the other hand the presence of nitrogen compounds was established by Beijerinck in *Streptococcus hollandicus*, and Hamm found bacterial capsules consisting of protein(3). It would thus appear that, although we can trace no near affinity of *Leuconostoc mesenteroides* with the Cyanophyceae on the grounds of its membrane the latter differs still more remarkably from that of certain other bacteria and in its carbohydrate nature would seem to be relatively primitive.

The genus *Leuconostoc* is thus allied to certain bacteria and must be provisionally placed in the Coccaceae. A more detailed analysis of the systematic characters of the various other representatives of this family will, of course, be necessary before their phylogenetic relationships can be fully understood. That *Leuconostoc* may be a fairly primitive member of this plexus is suggested by the fact that its mode of life is not so highly specialised as that of the majority of the Streptococceae and by its palmelloid character which, by analogy with the algae, must be regarded as a more primitive stage of development than the filamentous. The capsulated forms in the young colonies of the higher Streptococceae thus appear as phases recapitulating the ancestral type. The resemblance of *Leuco-*

nostoc to the Chroococcaceae in certain characters as mentioned above appears to be due to the common palmelloid nature rather than close systematic relationship since we have seen that *Leuconostoc* differs from this family in many details of taxonomic importance. *Leuconostoc* certainly cannot be regarded as derived from the Nostocaceae or other filamentous algae. It is likely that the palmelloid character in this genus has had an independent phylogenetic development from that of other bacterial and algal types.

In conclusion the writer wishes to acknowledge the kindness of those who have sent him specimens of *Leuconostoc* and related organisms, or information respecting them. Thanks are particularly due to Col. Wall, J.P. of West Ham, Dr Ashby of Barbados and Prof. Van der Bijl of Stellenbosch.

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SOME OBSERVATIONS ON THE MYCOPHAGOUS PROPENSITIES OF SLUGS.

By W. T. Elliott, D.D.S., F.L.S., F.Z.S.

During the years 1917–1920 the following observations were made in order to try and establish any fact showing that some species of slugs are more attracted by fungi as food than others, and to ascertain whether slugs have a preference for any particular fungi. This subject does not appear to have received much attention. Gain (1891) made an extensive series of observations on the food of mollusca generally, but only refers to ten species of fungi. He found that *Boletus edulis* is eaten with avidity by *Arion ater* and *Limax maximus*, that *Polyporus squamosus* is scarcely touched by *Arion hortensis*, *Agriolimax agrestis* and *Limax arborum*, whereas *Agriolimax agrestis* is

stated to attack not only *Boletus edulis*, but also *Amanita muscaria* and *Amanita phalloides*, apparently avoiding *Boletus luridus* (see Turton, p. 81).

The method I adopted was to keep from three to six of each species of slug under an inverted glass bowl that accurately fitted a saucer, in which either moss or earthy soil was placed, and the fungus either whole or cut to a suitable size was introduced, and allowed to remain for forty-eight hours. At the end of this period it was removed and the amount and parts that had been eaten duly noted. The slugs were not fed again for three days at least, before any other food was tried. The results as to preference for any particular part of the fungus show that sometimes the stipe was first attacked and in other cases the hymenium or the pileus, but they are as yet incomplete and require further confirmation, so that they are not given in the table herewith.

The following remarks may be made concerning the ten species of slug that have been used for the experiments.

Arionidae.

1. *Arion ater* is extremely voracious and omnivorous. It will devour decomposing or living animal matter and also its own fellows, in fact, almost anything, paper, or sand (Cooke, p. 31), also the poisonous berries of *Arum maculatum*, as well as poisonous fungi such as *Amanita pantherina*.

2. *Arion subfuscus* usually prefers non-chlorophyllaceous material as its food, as also does *Arion intermedius* and *Limax maximus*, hence, as would have been anticipated, these species possess a great partiality for fungi. Taylor (p. 196), referring to *A. subfuscus*, says that *Phallus impudicus* was greedily devoured, but the animals died soon afterwards.

3. *Arion circumscriptus* is a geophilous slug, and, so far as my observations go, does not appear to be very partial to fungus food, yet it may often be found in the stipe and pileus of many Agarics.

4. *Arion intermedius*, known as the hedgehog slug, is apparently purely mycophagous. It frequents uncultivated ground where fungi abound, and refuse where fungoid growths are developing.

5. *Arion hortensis* is another geophilous species, and is a chlorophyll feeder, being rarely found on fungi: it does not apparently seek fungi for food, but I have observed that it devours three species of Russula with avidity.

Limacidae.

6. *Limax maximus* is an omnivorous feeder, having a partiality for kitchen refuse, such as fat, meat scraps, and milk, but it avoids those substances that contain chlorophyll. It has

cannibalistic propensities and its preference for fungus food is very marked.

7. *Limax cinereo-niger* is mainly mycophagous, its habitat being woods and forests where fungi abound. Stahl records that the food of this species was apparently solely fungi, as the excrementious matter was composed of partially digested hyphae and undigested spores (Taylor, p. 57). Prof. Buller (1909, p. 226) refers to the experiments by Voglino upon the dispersal of spores of Hymenomycetes by slugs and the conclusions may be that they do not materially exert much influence in that direction.

8. *Limax arborum* feeds exclusively on lichens. In three instances, however, it slightly tasted fungi (see table). I have kept this species for some months in captivity, when it refused food of any kind beyond what could be obtained from the dead wood in the cage. Its habitat being arboreal, it probably has changed its diet from fungi to lichens (see Taylor, p. 93).

9. *Milax sowerbyi* is not at all partial to fungi and has only eaten this food under compulsion.

10. *Agriolimax agrestis*, the common field slug, is exceedingly partial to chlorophyllaceous food, as all farmers and gardeners can testify, it being very destructive. Its olfactory sense for chlorophyll is very marked, for it quickly finds young seedling plants, which it greedily devours. Still, at the same time, it will readily devour certain fungi, earthworms and insects, and as a feeder is very similar in its propensities to *Arion ater*. Its habitat is variable and its food is just as varied. Taylor (p. 108) says that it is not usually a fungus eater, but at times feeds upon various kinds, both poisonous and edible, such as *Amanita muscaria*, *Boletus edulis*, etc.

It is very evident, therefore, that some species have a marked taste for chlorophyll food although no slug actually favours it entirely. On the other hand, *Arion subfuscus*, *A. intermedius*, *Limax maximus* and *L. cinereo-niger* are decidedly mycophagous, but will eat chlorophyllaceous food under compulsion. Slugs in comparison eat very much more food than snails; obviously the reason being to repair the great waste from the excessive muscular action required in moving to and fro to cover and safety. It is seldom that we find a large fungus that has not been attacked by a slug and also it is seldom one finds more than one animal on the fungus, but it rarely happens as at 5 a.m. on an October morning (22. x. 16) with the sun rising and light fleecy clouds in the sky, and with the sheep tracks showing a heavy dew, that Puff-balls, Liberty Caps and Mushrooms in abundance were to be seen quite clean and not touched by a single slug.

Sense of Smell.

The olfactory sense is very highly developed in the mollusca generally, and is of more value to them than sight. Most authorities regard this sense as being situate in the tentacles. Moquin-Tandon (1851) made experiments by removing the tentacles, and he was satisfied that the animal then lost this sense or nearly so. Sochaczewer (1881) located this sense in a pedal gland near the mouth. Simroth (1882) says that it is distributed over the entire soft integument, as well as being concentrated in the tentacles, and near the respiratory orifice (Cooke, p. 192). Many experiments are recorded showing how acutely perceptive these animals are with the olfactory sense in the matter of food, but especially so with fungi.

Buller (1922) recorded an interesting series of observations he had made with *Limax maximus* and *Phallus impudicus*. He observed that the former found its way back many times to the Phallus by its sense of smell, even when removed from it to a considerable distance.

Blood and Nervous System.

Molluscan blood generally is colourless and devoid of red corpuscles. Haemoglobin as found in the blood of vertebrates is not present except in a few cases, for mollusca do not require great facilities for oxidisation, since being otiose, it is not necessary for the oxygen to be generally diffused. Haemocyanin, an albuminoid containing copper, largely replaces this haemoglobin. Its functions are similar, but less effective. Haemoglobin, however, is present in the buccal tissues of some species, since this is a part where energetic action is called for, also white corpuscles or amoebocytes occur much resembling those found in man (see Cooke, p. 171). This variation in the composition of the blood, as compared with that of man, may account for the fact that phallin, a solvent of red blood corpuscles, an alkaloid which is found in fungi, and poisonous to man, has no toxic effect on slugs. Muscarin, also, another alkaloid present in fungi producing a toxic effect on man since it causes paresis of the heart's action, is without effect on slugs because of their simpler nervous system; for these animals do not possess anything analogous to the sympathetic system in man which controls the heart's action; or it may be, these alkaloids are not absorbed by the molluscan tissues, and pass out through the alimentary tract.

The conclusions that may be deduced from these experiments below are:

1. *Arion ater*, *A. intermedius* and *Limax maximus* are extremely

partial to fungus food, that *Limax arborum* is not a fungus eater, and that *Agriolimax agrestis* has no partiality for this food.

2. The so-called poisonous and non-poisonous fungi have no relative effect upon slugs; although *Coprinus micaceus* killed those slugs left with the decomposing material, and *Arion ater* upon two occasions died after devouring with avidity *Russula emetica*.

3. Those fungi possessing cystidia, such as *Inocybe rimosa* and *Pluteus cervinus* are readily eaten. Buller (1909, p. 18) states that the significance of cystidia does not appear to have been elucidated with any certainty. Possibly in some cases they serve to protect the fruit bodies from slugs or other animal parasites. In certain Russulae they do not seem to render the gills unpalatable to slugs since the species of this genus are invariably attacked by them, although we find in the case of green plants that prickly or hairy investments and hard siliceous material are a protection against molluscan teeth. Cultivated plants generally in this respect being not so adequately protected are more readily attacked. Those species of Graminaceae, Equisetaceae and Cyperaceae, where minute acicular crystals of calcium oxalate are present, act as an irritant in the mouth of mollusca.

4. The chemical defences in green plants, such as acrid juices, alkaloids, nauseous secretions, etc. are a deterrent against slugs, yet fungi containing alkaloids such as Amanitae and acrid juices such as Russulae are not avoided. However, certain fungi having a viscid exterior such as *Gomphidius viscidus* and *Hebeloma mesophaeum* are refused, yet the viscid *Stropharia aeruginosa* is devoured. Buller (*l.c.*) says that the presence of nauseous or distasteful substances in the cellular structure appear to be protective against slugs.

5. Slugs are partial to all the species of Russulae and the poison that affects man has quite a diverse effect by reason of the chemical or physiological constitution of the blood and the simplicity of the nervous system.

6. They refuse tough and hard fungi, such as *Scleroderma vulgare* and *Panus stypticus*. Johnson (1920) says of *Panus stypticus* "one of the many fungi eaten by slugs: they cause the rapid disappearance of young sporophores and bite large pieces out of mature ones." This refers to natural conditions.

7. In conclusion, there appears to be no special property in fungi that makes them objectionable, or, on the other hand, that makes them attractive as food. Buller (*l.c.*) gives the results of experiments with three species of slugs, viz. *Limax maximus*, *Arion subfuscus* and *Agriolimax agrestis*, upon twelve species of fungi and these generally agree with those in the appended table.

Experiments with 60 *species of fungi.*

E = Eaten entirely or with avidity.
S = Slightly eaten.
N = Not touched or refused.

	Experiments	E	N	S
Arion ater	24	13	2	9
,, subfuscus	20	4	4	12
,, circumscriptus	2	—	—	2
,, intermedius	2	2	—	—
,, hortensis	13	5	4	4
Limax maximus	42	21	7	14
,, cinereo-niger	35	16	7	12
,, arborum	9	—	6	3
Milax sowerbyi	8	—	3	5
Agriolimax agrestis	15	1	10	4
	170	62	43	65

	Mixed slugs	Arion ater	A. subfuscus	A. circum-scriptus	A. intermedius	A. hortensis	Limax maximus	L. cinereo-niger	L. arborum	Milax sowerbyi	Agriolimax agrestis
Amanitopsis vaginata	E	E	—	—	—	—	—	—	—	—	—
Amanita pantherina	—	S	—	—	—	—	S	N	—	—	—
Boletus flavus	—	—	S	—	—	S	S	S	—	—	S
,, chrysenteron	—	—	—	—	—	—	S	—	—	—	—
,, luridus	S	—	—	—	—	—	E	—	—	—	—
,, lactifluus	—	—	—	—	—	—	—	E	—	—	—
Coprinus micaceus	—	—	—	—	—	—	S	E	N	S	—
,, niveus	—	E	—	—	—	—	N	N	—	—	—
Craterellus cornucopioides	—	—	—	—	—	—	—	—	S	—	—
Collybia dryophila	—	—	—	—	—	—	—	N	—	—	—
,, platyphylla	—	—	S	—	—	—	E	—	—	—	—
,, esculenta	—	—	—	—	—	—	—	E	—	—	—
Clitopilus prunulus	—	S	—	—	—	—	N	S	S	S	N
Cortinarius purpurascens	—	—	—	—	—	E	—	—	—	—	—
Entoloma lividum	—	—	—	—	—	E	—	—	—	—	—
Galera hypnorum	—	—	—	—	—	—	E	E	—	—	—
,, tenera	N	E	—	—	—	—	—	—	—	—	—
Gomphidius viscidus	—	S	—	—	—	—	S	—	N	—	—
Hypholoma epixanthum	—	—	—	—	—	—	S	S	—	—	—
,, fasciculare	—	E	S	S	—	S	E	S	N	—	S
,, sublateritium	—	E	—	—	—	—	—	—	—	—	—
Hygrophorus psittacinus	—	—	S	—	—	N	E	E	—	—	N
,, puniceus	—	—	—	—	—	—	S	S	—	—	—
,, coccineus	—	—	—	—	—	—	—	N	—	—	—
,, pratensis	—	—	—	—	—	—	—	S	—	—	—
,, virgineus	—	—	—	—	—	—	—	S	—	—	—
Hebeloma fastibile	—	—	—	—	—	—	E	E	—	—	—
,, mesophaeum	—	E	S	—	—	—	S	E	N	N	N
Inocybe rimosa	—	—	—	—	—	—	E	—	—	—	—
Laccaria laccata	—	E	S	—	—	S	E	E	—	—	S
Lepiota granulosa	—	E	S	—	—	—	S	S	—	N	N
Lactarius deliciosus	N	E	N	—	—	—	S	—	—	—	—
,, rubra	S	S	—	—	—	—	S	S	—	—	—
,, quietus	E	—	—	—	—	—	S	—	—	—	—
,, subdulcis	S	—	—	—	—	—	S	—	—	—	—
Marasmius epiphyllus	—	—	N	—	—	N	—	N	—	—	N

	Mixed slugs	Arion ater	A. subfuscus	A. circum-scriptus	A. intermedius	A. hortensis	Limax maximus	L. cinereo-niger	L. arborum	Milax sowerbyi	Agriolimax agrestis
Mycena galericulata	S	E	E	S	—	—	E	S	—	—	N
,, sanguinolenta	—	—	N	—	—	N	E	E	—	—	N
Naucoria escharoides	—	E	—	—	—	—	E	—	—	—	—
Panaeolus campanulatus	—	—	—	—	—	—	S	N	—	—	—
,, papilionaceus	S	—	S	—	—	—	E	—	—	—	—
Pholiota squarrosa	—	—	—	—	—	S	—	E	—	S	—
,, terrigena	—	E	—	—	—	—	E	E	N	S	—
,, aurea	—	—	—	—	—	—	N	—	—	—	—
Polyporus sulphureus	—	—	S	—	—	—	E	—	—	—	—
Polystictus versicolor	S	—	—	—	—	—	N	—	—	—	—
Paxillus involutus	—	N	—	—	—	—	N	—	—	—	—
Panus stypticus	—	S	S	—	—	—	N	S	—	S	N
Pleurotus ostreatus	—	—	—	—	—	—	E	—	—	—	—
Psalliota arvensis	—	—	—	—	—	—	—	S	S	—	—
Pluteus cervinus	—	S	—	—	—	—	E	E	—	—	—
Russula cyanoxantha	E	E	S	—	—	—	E	—	—	—	—
,, subfoetens	—	—	—	—	—	E	E	E	—	—	—
,, rubra	—	S	E	—	E	—	—	—	—	—	—
,, fragilis	—	—	—	—	—	E	—	—	—	—	—
,, emetica	—	E	E	—	E	E	E	E	—	—	E
Scleroderma vulgare	—	—	N	—	—	N	N	N	—	—	N
Stropharia aeruginosa	—	—	—	—	—	—	E	E	—	—	N
Tricholoma personatum	—	S	S	—	—	—	E	E	N	N	S
Ulocolla foliacea	—	S	—	—	—	—	—	—	—	—	—

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PRELIMINARY LIST OF MANITOBA FUNGI.

By G. R. Bisby and A. H. R. Buller.

Manitoba extends north of Minnesota and North Dakota from the 49th to the 60th parallels of latitude. Manitoba is, therefore, in the same latitude as the British Isles, and extends, roughly, from the parallel of Paris and Vienna to that of Christiana and Petrograd. Climatic conditions are quite different, however, from those of most of the corresponding area in Europe.

Many species of Phanerogams attain their northern limits in Manitoba, and various plants reach their eastern or their western limits in this province, which marks a transition from a wooded rocky region in the eastern part to drier plains in the western portion. Manitoba is a region of considerable mycological interest.

This list is very incomplete: in only a few groups, such as the rusts and polypores, has anything more than a general preliminary survey been made, and in no case can this list purport to approach completeness. It does, however, serve to extend the range for a considerable number of species of fungi, and records the occurrence of such fungous diseases as have been observed, especially during 1920 and 1921, in the province. The collections have practically all been made in the southern quarter of the province, and principally below the 51st parallel. One trip was made to the Swan River Valley, just above 52° north latitude. The fungi of eastern Manitoba are represented largely by collections from Kenora and Minaki, which are in Ontario, but near the Manitoba line, and which are representative of conditions in south-eastern Manitoba. The highly interesting far north of Manitoba is as yet little surveyed for fungi.

This list to a considerable extent is dependent upon, and its accuracy is greatly heightened by, determinations made by various specialists. Grateful acknowledgment is made to those who have determined or corroborated the determinations of various specimens, and also to Professor V. W. Jackson, Mr I. L. Conners (marked "I.L.C."), and others who have aided in making collections, and in determining hosts. The initial of those who have made determinations of fungi is given in each case: if no initial follows, the identification is by the writers. The key to these initials is as follows:

Br. = Dr J. F. Brenckle, Kulm, N.D. Pyrenomycetes, etc.
B. = Dr E. A. Burt, Missouri Botanic Gardens, St Louis, Mo. Thelephoraceae, etc.

D. = Dr J. J. Davis, Univ. of Wisconsin, Madison, Wis. Parasitic fungi.
E. = Dr W. T. Elliott, Arden Grange, Tanworth-in-Arden, Warwickshire, England. Myxomycetes.
F. = Prof. W. P. Fraser, Univ. of Saskatchewan, Saskatoon, Sask. Rusts, etc.
J. = Prof. H. S. Jackson, Purdue Univ., Lafayette, Ind. Certain Rusts and Smuts.
K. = Dr C. H. Kauffman, Univ. of Mich., Ann. Arbor. Mich. Certain Agaricaceae.
L. = Miss G. Lister, Leytonstone, England. Myxomycetes.
Ll. = Mr C. G. Lloyd, 309, W. Court St., Cincinnati, Ohio. Various Hymenomycetes.
V. = Dr L. O. Overholts, State College, Pa. Polypores, etc.
S. = Dr F. J. Seaver, New York Botanical Gardens, New York City. Certain Ascomycetes.
W. = Miss E. M. Wakefield, Kew Gardens, Surrey, England. Various fungi.

In addition to these, other specialists whose names are given have determined certain species.

Specimens from 500 to 1000 inclusive are at the University of Manitoba; other numbers are at the Manitoba Agricultural College. Where no locality is cited, Winnipeg or its environs is to be understood. Where no collector's name is given, one or the other of the writers made the collection; the number indicates which one. Thus, "Arcyria occidentalis Lister, 673*L*, 343*E*" means that both specimens were collected at Winnipeg, No. 673 by A. H. R. Buller, part of the collection being sent to Miss Lister, who made the determination; the remainder is filed at the University of Manitoba. No. 343 was collected by G. R. Bisby, and part of it sent to Dr Elliott, who furnished the name, the remainder being deposited at the Manitoba Agricultural College. It was not considered necessary to include dates of collection unless they were out of the ordinary. Collections from the Swan River Valley were made on July 1st to 13th, 1921; from Gilbert Plains and Ste. Rose du Lac and vicinity, July 25th to 31st, 1921. Collections from Minaki and Kenora have been made principally in September and October, and by A. H. R. Buller unless otherwise noted.

Where no number is given in connection with a species the specimen is not preserved, but its authenticity is considered reasonably accurate, unless a question-mark is appended.

This list is believed to cover nearly all the species of fungi that have ever been collected in Manitoba. The writers have gone over the list of the Manitoba fungi which are at Ottawa and have checked over the rust and smut portions of the North American Flora as well as certain other publications which might contain references to fungi from Manitoba. Apart from the collections of the writers and Messrs Fraser, Conners, and V. W. Jackson, probably few collections of fungi from this province have been made. Various references to Canadian fungi were checked, but in practically every case no collections had

been made in Manitoba, except in the case of Professor Macoun's list of lichens. References to various Manitoba fungi are, however, given in "Researches on Fungi" and other papers by A. H. R. Buller.

The nomenclature used varies somewhat: Dr Kauffman was followed for names of Agarics, Dr Overholts for Polypores, and Saccardo for many fungi. In general the writers have endeavoured to use the standard names for the fungi included. The names of hosts are taken largely from Britton and Brown's Flora.

Dr Davis has furnished the description of a new Cercospora for this list, and Mr Lloyd has considered a Ptychogaster sent him to be a new form. Two or three species are recorded for the first time for North America. In almost every case, however, the fungi found were those which had already been described for North America. Further and more critical search will of course extend this list, and the writers believe that a survey of Northern Manitoba will reveal a number of interesting fungi.

This list contains 574 fungi, as follows: Myxomycetes 34, Bacteria 8, Phycomycetes 20, Ascomycetes 62, Imperfect fungi 38, Smuts 20, Rusts 80, Polypores 63, Agarics 108, Thelephoraceae 36, other Basidiomycetes 57, Lichens 48.

MYXOMYCETES.

Parasitic species have not been found in Manitoba.

Acrasieae: Dictyostelium mucoroides Bref., observed by A. H. R. B.
Exosporeae: Ceratiomyxa fruticulosa (Muell.) Macbr., 326*E.*, 1111, twice found in abundance on old wood.
Endosporeae: Arcyria denudata (L.) Wettst., 674*L.*
A. incarnata Pers., 658*E.*
A. incarnata var. fulgens Lister, 675*L.*
A. occidentalis Lister, 343*E.*, 645*E.*, 673*L.*
A. stipata Lister, 1241*L.*, 1242*L.*
Badhamia macrocarpa (Ces.) Rost., 659, 660.
B. panicea (Fr.) Rost., 643*E.*
Comatricha irregularis Rex., Carman, A. R. Skinner, 676*L.*
Craterium leucocephalum (Pers.) Dittm., 340*E.*
Diderma globosum Pers., 646*E.*, 647, 677*L.*, 1179*L.*
D. spumarioides Fr., fruiting on grass and leaves, 1245*L.*, 1246*L.*
Didymium melanospermum (Pers.) Macbr., 1249*L.*
D. squamulosum (A. and S.) Fr., 665, 782, 341*E*
Enteridium Rozeanum (Rost.) Wing, 656*E.*
Fuligo septica (L.) Gmel., 357*E.*, 522, 648, 649, 780, 781.
F. septica var. candida Pers., 1247*L.*
Hemitrichia clavata (Pers.) Rost., 663, 657, 783*E.*, 1240*L.*, 1243*L.*
H. Vesparium (Batsch) Macbr., 678*L.*
Lamproderma violaceum (Fr.) Rost., Victoria Beach, 963*L.*
Lycogala epidendrum (L.) Fr., 345*E.*, 620, 653, 654, 655, Swan River, 1035. Very common.
Mucilago spongiosa (Leys.) Morg., 342*E.*, 767, 775, 779, 1250*L.*
Perichaena corticalis (Batsch) Rost., 426*L.*
Physarum auriscalpium Cke., 344*E.*
P. connatum (Peck) Lister, 651*E.*, 679*L.*, 1244*L.*, 1248*L.* Common.

P. contextum Pers., 680*L*.
P. didermoides (Ach.) Rost., 664, det. Cheesman.
P. nutans Pers. var. leucophaeum Lister, 1243*L*.
P. sinuosum (Bull.) Weinm., 681*L*.
Stemonitis fusca Roth., 304, 644, 618, 683*L*. Common.
Trichia contorta Rost. var. inconspicua Lister, det. *E*. No specimens at Winnipeg.
T. persimilis Karst., 652*E*.
Tubifera ferruginosa Gmel., det. *E*. No specimens at Winnipeg.

BACTERIA.

These few species have been found as plant parasites in Manitoba. Other forms of course occur, but in general bacterial diseases of plants seem to be comparatively indestructive here.

Bacterium translucens J. J. and R., on Hordeum vulgare, 235. Collected and determined by I. L. Conners.
B. translucens var. undulosum S. J. and R. Black chaff is occasional on Triticum aestivum.
Bacillus amylovorus (Burr.) de Toni, on Pyrus Malus, 1099. Quite abundant in 1921.
B. atrosepticus v. Hall, on Solanum tuberosum, 224. A rather serious disease in wet and cool years. Not abundant in 1921.
B. carotovorus Jones, on celery, cabbage and other vegetables.
Pseudomonas Phaseoli E. F. Sm., on Phaseolus vulgaris, causing some loss, 471, 1084.
P. radicicola (Bet.) Moore, on various legumes, 794, 795; wherever legumes grow.
Bacterial Spot on Sudan grass at Winnipeg (Bacillus Sorghi Burr.?), 1153*D*.

PHYCOMYCETES.

None of the Phycomycetes has been found to cause any particular damage to agricultural crops. *Phytophthora infestans* is conspicuous by its absence.

Albugo Bliti (Biv.) O. Kuntze, on Amaranthus retroflexus, 128.
A. candida (Pers.) O. Kuntze, on Brassica sp., 188; on Raphanus sativus, 170.
A. Tragopogonis (DC.) S. F. G., on Cirsium arvense, Ste. Rose, 1169*D*.
Basidiophora Kellermanii (E. and H.) Wilson, on Iva xanthifolia. Reported by W. P. Fraser at Dauphin and elsewhere.
Cladochytrium Alismatis Buesg., on Alisma subcordata, coll. R. Broadfoot, det. I. L. C.
Empusca Muscae Cohn. On house fly, 356.
Mucor Mucedo (L.) Bref., Winnipeg, A. H. R. B.
M. racemosus Fres., A. H. R. B.
Peronospora effusa (Grev.) Rbh. (?). On Chenopodium album, coll. I. L. C.
P. Trifoliorum de By., on Medicago sativa, Brandon, I. L. C., 1154.
Plasmopora Halstedii (Farl.) Berl. and de Toni, on Ambrosia artemesifolia, Ste. Rose, 1134*D*.
P. obducens Schroet., on Impatiens biflora, Swan River, 1140*D*.
Phycomyces nitens (Agardh) Kunze, A. H. R. B.
Pilobolus longipes van Tiegh., on dung, A. H. R. B.
P. crystallinus (Wigg.) Tode, on dung, A. H. R. B.
Piptocephalis Freseniana de By., A. H. R. B.
Rhizopus nigricans Ehr. Common, sometimes semiparasitic on stored vegetables, etc.
Saprolegnia sp. on fish, etc.
Sporodinia grandis Link, on Lentinus lepideus, I. L. C., 1097.
Synchytrium decipiens Farl., on Amphicarpa monoica, 116, Morris, I. L. C., 109. Common.

ASCOMYCETES.

Saccharomycetales: Saccharomyces sp. in fruits of Prunus sp. (wild plum), 1208. Other "wild" yeasts also occur.
Protodiscales: Exoascus Pruni Fcl., on Prunus spp. 305, 325, Dominion City, 578. Common on plums.
Helvellales: Gyromitra esculenta (Pers.) Fr., Kenora.
Helvella crispa (Scop.) Fr., Gimli, 640, 764.
H. lacunosa Afzel., Russell, 1093.
Leotia lubrica (Scop.) Pers., Kenora, A. H. R. B.
Morchella esculenta (L.) Pers., 322, 393, 444, 439. Common.
M. conica Pers. (probably only a form of M. esculenta); Hillside Beach, 411
M. crassipes (Vent.) Pers., 788; Hillside Beach, 410; Minaki.
Spathularia clavata (Schaeff.) Sacc., Minaki, A. H. R. B.
Verpa conica (Mill.) Swartz, Hillside Beach, 409.
Pezizales: Ascobolus immersus Pers., on dung, Winnipeg, A. H. R. B.
Cenangium furfuraceum (Roth) de Not., 734*B*.
C. populneum (Pers.) Rehm, 919*S*.
Chlorosplenium aeruginosum (Oed.) de Not., Shoal Lake S.E. Man., I. L. C., 432; Kenora, 551, 711.
Coryne? sp., near Kenora, 911*S*.
Helotium citrinum (Hedw.) Fr., 384*S*., 407*S*., 1167*Ll*., 916, 926; near Kenora, 912*S*.
Lachnea scutellata (L.) Gill., Kenora, A. H. R. B.
Mollisia cinerea (Batsch) Karst., 401*S*., 420*S*.
Orbilia sp., 910*S*.
Peziza aurantia Muller, Minaki, 863.
P. badia Pers.? Hillside Beach, 412.
P. vesiculosa Bull., 363, 765.
Pseudospeziza Medicaginis (Lib.) Sacc. on Medicago sativa (cult.), 296; Brandon I. L. C., 1155; Swan River, 485.
Sclerotinia libertiana Fcl. on carrots, parsnips and other vegetables. What is considered to be this species has also been collected on Helianthus annuus (cult.), 609, causing a serious stem rot, and on Iva xanthifolia, 102, Cirsium arvense, Helianthus tuberosus, and Sonchus arvense.
Phacidiales: Propolis faginea (Schrad.) Karst., near Kenora, 913*S*.
Rhytisma salicinum (Pers.) Fr., on Salix sp., 90; Gilbert Plains, 1061.
Hysteriales: Hysterographium Fraxini (Pers.) de Not., on Ash wood, 1101*Br*.
Aspergillales: Aspergillus herbariorum (Wigg.) Fisch. Common.
Penicillium spp. The usual blue moulds on various substances.
Perisporiales: Dimerosporium Collinsii (Schw.) Thuem., on Amelanchier alnifolia, 820. Common.
Erysiphe Cichoracearum DC., on Helianthus annuus (cult.), 307; on Ambrosia trifida, Morris, I. L. C., 103.
E. Galeopsidis DC., on Stachys sp., Ste. Rose, 1070.
E. Graminis DC., on Secale cereale, 135. Not serious.
E. Polygoni DC., on Polygonum aviculare, 174, 300; Virden, 289; Swan River, 477; on Pisum sativum (cult.), 1087.
Microsphaera Alni (Wallr.) Wint., on Quercus macrocarpus, J. J. Christensen and G. R. B., 308.
M. diffusa Cke. and Pk. On Lathyrus odoratus, 288. Common.
Podosphaera Oxyacanthae (DC.) de By., on Prunus pumila, Dauphin, F. W. Brodrick, 1175, det. I. L. C.
Sphaerotheca Humuli (DC.) Burr. var. fuligina (Schl.) Salm., on Viola (cult. pansy), 1189; on Taraxacum officinale, Swan River, 491.
Uncinula Salicis (DC.) Wint., on Salix spp. and Populus spp. 148; Virden, 292; Grand Beach, 183; Victoria Beach, 1091.
Hypocreales: Claviceps purpurea (Fr.) Tul., on Agropyron tenerum, Bromus inermis, Calamagrostis canadensis, Elymus canadensis, E. innovatus, Panicularia grandis, Secale cereale, Triticum aestivum, 119, 118, 197, 269; I. L. C., 152, F. J. Higham, 124; Deloraine, 111; Clandeboye,

V. W. Jackson, 1197; Roblin (W. Rae); common and often destructive to wild grasses, common on rye.

Gibberella Saubinetii (D. and M.) Sacc. Fusarium stage on Triticum aestivum, W. H. Mackie Aug. 1920, 374. Quite common in 1921.

Hypomyces lactifluorum (Schw.) Tul. On Lactarius piperatus, L. spp., 333, 581, Gimli, 582, Minaki, 786. Very common.

Nectria cinnabarina (Tode) Fr. On Prunus spp., 395; Stony Mountain, 891; Swan River, 1032.

N. episphaeria (Tode) Fr., near Kenora, 914*S*.

N. Peziza (Tode) Fr., St Charles, 949*S*.

Dothidiales: Phyllachora graminis (Pers.) Fcl., on Elymus virginicus, E. canadensis, 72; Neepawa, I. L. C., 108.

Plowrightia morbosa (Schw.) Sacc., on Prunus spp., Virden, 287; Stony Mountain, 892; Swan River, 1033. Very common, and often destructive on wild plums, etc.

Sphaeriales: Anthostoma adustum (C. and P.) Sacc., on old wood, 1168*Br*.

Daldinia concentrica (Bolt.) Ces., on wood, 231, 327, 842, 438; Swan River, 1025.

Didymosphaeria manitobiensis Ell. and Ev., on Rubus (probably R. strigosus), coll. J. Dearness on banks of little Saskatchewan River, Oct. 3, 1891. Reference in N.A. Pyrenomycetes, p. 732. Specimen at Ottawa, from original collection.

Diatrype spp., 948*Br*., 423*Br*.

Gnomonia ulmea (Schw.) Thuem. Conidial stage on Ulmus leaves, J. J. Christensen and G. R. B., 315*D*.

Gnomoniella Coryli (Batsch) Sacc., on Corylus americanus leaves, 179.

Hypoxylon commutatum Nits., on old wood, 947*Br*.

H. fuscum (Pers.) Fr., on old wood, 733*B*., 954*S*.

H. Morsei B. and C., on wood, I. L. C. and G. R. B., 425*Br*.

H. rubigninosum (Pers.) Fr., 739*B*.

Lasiosphaeria strigosa (Alb. and Schw.) Sacc., on wood, 421*S*.

Physalospora Cydoniae Arnaud, Sphaeropsis stage on leaves of Pyrus malus, Morden, coll. A. V. Mitchener, 1050 det. H. T. Güssow. This fungus has not been found to be common on apple.

Valsa translucens de Not., on wood, 937*Br*.

Venturia inaequalis (Cke.) Aderh., on leaves of Pyrus malus, 216, 324, 187. Common but not ordinarily serious on apple.

FUNGI IMPERFECTI.

This list of imperfect fungi is obviously very incomplete. Most of the identifications are by the courtesy of Dr Davis. Few saprophytic forms have been collected.

Alternaria Solani (E. and M.) Jones and Grout, on potato leaves, Gilbert Plains, 1062; common over Manitoba in 1921 but not serious.

Asteroma Gentianae Fcl., on Dasystephana (Gentiana) Andrewsii, 1138*D*. Dr Davis reports that this fungus has been confused with Phyllosticta (Depazea, Leptothyrium) gentianaecola.

Botrytis Paeoniae Oud., on Paeony (cult.), 89. Sometimes injurious.

Cephalothecium roseum Cda., on citron fruit, 298; on Prunus fruit, Swan River, 1074; on Lentinus, 1098.

Cercospora althaeina Sacc., on cultivated hollyhock, 1132*D*.

C. avicularis Wint., on Polygonum aviculare, Lazare, 1128*D*.

C. dubia (Reiss) Wint. (C. Chenopodii Fres.), on Chenopodium album, Carberry, I. L. C., 1157*D*.

C. manitobana J. J. Davis, sp. nov. Spots brown, subcircular, 1–5 mm. in diameter above, less distinct below; conidiophores hypophyllous, fasciculate, fuligenous, straight or incurved or somewhat undulate, simple, sometimes septate, more or less nodulose, 35–60 × 3–4 μ; conidia hyaline, obclavate, straight, becoming 1-septate, 50–63 × 4–6 μ.

On leaves of Shepherdia argentea, Gilbert Plains, Manitoba, coll. July 27, 1921, G. R. Bisby, No. 1125. Type in J. J. Davis' collections, co-type at Man. Agr. College. The trichomes give a somewhat cinereous appearance to the spots.

C. rhoina C. and E., on Rhus Toxicodendron, Thunder Hill, 1136*D*.

Cladosporium subsessile Ell. and Barth., on Populus leaves, 316*D*. Common.

Colletotrichum salmonicolor O'Gara, on stems of Asclepias sp., 318*D*.

Cylindrosporium Padi Karst. (Coccomyces), on leaves of Prunus, 311; Eden, 459.

Cystospora chrysosperma (Pers.) Fr. (Valsa sordida Nke.?), on Populus, J. F. Higham, 446.

Darluca filum (Bib.) Cast., on sori of rusts. Common, especially on telia late in the season.

Discosia artocreas Fr. (?), on Rubus triflorus, 374*D*.

Fusarium conglutinans callistaphi Beach, on Aster (cult.) causing wilt. Common. The fungus was not fully determined as to species but is probably the above.

F. discolor sulphureum Schl., on potato tubers, causing rot. A number of isolations indicated that this is the commonest Fusarium in rotted potatoes in Manitoba.

F. Lini Bolley, on flax (cult.). Not common; definite record only from Winnipeg.

F. oxysporum Schl., on potato. Wilt of potatoes in Manitoba was found, so far as isolations were made, to be caused by this Fusarium.

Haplosporella diatrypoides E. and B.(?), 392*B*.

Helminthosporium gramineum (Rab.) Erik., on barley, 159, 167, Ste. Rose, 1010. Common and sometimes destructive.

H. sativum P. K. and B., on barley; Swan River, 495; everywhere in Manitoba causing considerable injury.

H. teres Sacc., on oats and barley, quite common but not found to be serious.

Phyllosticta livida E. and E., on Quercus macrocarpa, J. J. Christensen and G. R. B., 314*D*.

Ramularia Tulasnei Sacc. (apparently), on cult. strawberry, 123*D*.

R. Urticae Ces., on nettle, I. L. C. and G. R. B., 1191*D*.

Septoria conspicua E. and M., on Steironema ciliata, Ste. Rose, 1139*D*.

S. Convolvuli Desm., on Convolvulus sepium, Emerson, I. L. C., 1176*D*.

S. flagellifera E. and E., on Pisum sativum (cult.), 1150*D*.

S. lactucicola E. and M., on Lactuca sp. 317*D*. The same or a similar fungus also on Sonchus arvense.

S. musiva Pk., on Populus balsamifera, I. L. C., 1172*D*.

S. Oenotherae West, on Oenothera biennis, Gilbert Plains, 1126*D*.

S. ribis Desm., on Ribes (cult. gooseberry), 1194, 1195.

S. Sicyi Pk. (S. Brencklei Sacc.), on Micrampelis lobata, Morris, I. L. C., 313*D*.

S. Symphoricarpi E. and E., on Symphoricarpos sp., Morris, I. L. C., 319*D*.

Trichoderma lignorum (Tode) Harz, has been found.

Vermicularia (?; immature), on Smilax herbacea, 1130*D*.

Verticillium albo-atrum McA. Has been observed on rotting potato tubers.

BASIDIOMYCETES.

USTILAGINALES.

The writers have made no extended search for smuts in Manitoba, and this list includes principally conspicuous economic forms. The range of certain species is, however, extended. W. P. Fraser and I. L. Conners have helped in preparing this list.

Entyloma compositarum Farl., on Ambrosia trifida, Morris, I. L. C., 320*D*.
E. Menispermi Farl. and Trel., on Menispermum canadense, I. L. C., 194*D*.
Sorosporium Syntherismae (Peck) Farl., on Panicum milaceum, Keyes, 150*F*.
Sphacelotheca Sorghi (Link) Clinton, on Sorghum vulgare, 433.
Tilletia laevis Kuehn, on Triticum aestivum, listed by Clinton in N. A. Flora, VII, 48, 1906. This is the only smut from Manitoba listed in that work. The only bunt of wheat the writers have found is caused by T. Tritici; but T. laevis may also still occur in the Province.
T. Tritici (Bjerk.) Wint., on Triticum aestivum, 157. This smut is widespread over Manitoba, although not serious because of the common practice of treating seed wheat.
Urocystis Anemones (Pers.) Wint., on Pulsatilla patens, Brandon, W. P. F. and I. L. C., 380; also collected by Conners at Carberry.
U. occulta (Wallr.) Rab., on Secale cereale, V. W. Jackson, 299. Found by Prof. Jackson on volunteer rye beside the Biology Building, M. A. C.; also reported on the plots at the M. A. C., Winnipeg; not found in fields throughout the Province.
Ustilago Agropyri (?) on Agropyron tenerum, V. W. Jackson, 137. Common and more or less injurious to this grass.
U. anomala (J. Kunze) Wint., on anthers of Polygonum (Tiniaria) cilinode, A. H. R. B., Minaki.
U. Avenae (Pers.) Jens., on Avena sativa, 172, 310, Ste. Rose, 1011; Lonely Lake, 1072. Common and rather destructive to oats.
U. Hordei (Pers.) Kell. and Swingle, on Hordeum vulgare, Portage la Prairie, I. L. C., 107; Gilbert Plains, 1020. Common but does not cause much loss.
U. hypodytes (Schl.) Fries, on Stipa viridula, Rapid City, I. L. C., 173*F*.
U. levis (K. and S.) Magn., on Avena sativa, 309. Not very common.
U. Lorentziana Thuem., on Hordeum jubatum, Boissevain, I. L. C., 182*F*.
U. neglecta Niessl., on Chaetochloa glauca, 297.
U. striaeformis (West.) Niessl., on Beckmania erucaeformis, I. L. C. and H. Groh., 1088*J*. Prof. H. S. Jackson reports that this is the first time he has seen a smut on this host, but that the smut agrees with U. striaeformis though there may be strains.
U. Tritici (Pers.) Rostr., on Triticum aestivum, 176, 180, Oakville, V. W. Jackson, 302; Binscarth, 472; Gilbert Plains, 1066. Common, sometimes causing 10 % loss of wheat.
U. Zeae (Beckm.) Unger, on Zea Mays, Glenora, 358. Very prevalent in 1921.
U. sp. on Phragmites Phragmites. Delta, V. W. Jackson, 1089*J*. H. S. Jackson reports that this may possibly be U. mirabilis Sorokin, heretofore known only from Russia.

Uredinales.

List compiled with the assistance of W. P. Fraser and I. L. Conners.

The number of rusts in Manitoba is necessarily somewhat limited because of the short growing season, the relatively small range of hosts, and the absence of marked variation throughout the province in elevation, precipitation, etc.

The 80 species here listed fall in 19 genera. Only some eight species (five Puccinia, two Polythelis, one Nyssopsora) are short cycled (telia only or pycnia and telia).

The North American Flora (vol. VII) has in general been followed, except that Puccinia and Uromyces names are used.

Aecidium Allenii Clinton, I on Eleagnus argentea, Russell 1002. Probably a stage of Puccinia Rhamni.

Calyptospora columnaris (Alb. and Schw.) Kuehn, III on Vaccinium sp., Minaki.

Coleosporium Solidaginis (Schw.) Thuem., II on Solidago spp. 149, Swan River Valley, 476, 481; Ste. Rose du Lac, 1058; Lonely Lake, 1073; Victoria Beach, 1086; on Aster spp. 146, 1083, Grand Beach, 146; on cultivated asters, 1187; on Doellingeria sp., Lonely Lake, 1056. The mycelium of this rust overwinters in the perennial parts of the plants; aecia have not been found here.

Cronartium Comandrae Peck, II, III on Comandra pallida, Victoria Beach; V. W. Jackson, 1090; common.

Earlea speciosa (Fries) Arth., on Rosa spp., Brandon and Oak Lake, W. P. F.; Eden, 461; Morris, I. L. C., 127; common.

Gymnoconia interstitialis (Schl.) Lagerh., I on Rubus triflorus, Ochre River, V. W. Jackson, 236; Eden, 452. This interesting rust (the longer cycle form) occurs commonly in northern regions. Germination of the aeciospores of the Eden collection showed that they produced germ tubes.

Gymnosporangium cornutum (Pers.) Arth., I on Sorbus americana, Minaki, 611.

G. germinale (Schw.) Kern., I on Crataegus sp., 218. Not uncommon.

G. juvenescens Kern., I on Amelanchier alnifolia, 75, 199, 247*J*.; Eden, 458. Collected also at Brandon and Rapid City, I. L. C.; III on Juniperus horizontalis, Millwood, 497. Frequently found on Amelanchier.

Melampsora Bigelowii Thuem., on Salix spp., Gilbert Plains, 1016; common throughout the Province; collected by V. W. Jackson along the Hudson Bay Railway, 241. "Overwinters in buds and twigs, the uredinia sometimes occurring on opening leaves in the spring." W. P. F.

M. Lini (Schm.) Desmaz., I, II, III on Linum usitatissimum, 229, 1129. II abundant on volunteer flax, collected as late as Oct. 8, 1920, 284. A rather serious disease of flax in Manitoba. II on Linum Lewisii, Russell, 1006; Baldur, I. L. C., 1147.

Melampsorella elatina (Alb. and Schw.) Arth., I on Abies balsamea, Brandon, I. L. C.; II on Cerastium arvense, Brandon, W. P. F.

Melampsoropsis Pyrolae (DC.) Arth., II, III on Pyrola rotundifolia, W. P. Fraser and V. W. Jackson, 251.

Nyssopsora clavellosa (Berk.) Arth., III on Aralia nudicaulis, 1081; Swan River, 1079.

Phragmidium americanum Diet., on Rosa sp. (cult.), 125; reported also from Brandon. This and the other Phragmidia on roses are referred with some doubt as to specific name.

P. imitans Arth., on Rubus strigosus, Brandon, I. L. C., (III) 226*J*.; (II) 227.

P. montivagum Arth., on Rosa blanda, Virden, 222, Morris, I. L. C. Wild roses as far north as Swan River are abundantly affected with rust. Several collections are only in the aecial stage, and it is not certain to which species they belong.

P. Potentillae (Pers.) P. Karst., I, II, III on Potentilla bipinnatifida, P. pennsylvanica, P. strigosa, P. glabrella, P. spp.; Virden, 130*J*.; Lake Clementi, I. L. C., 178, Reston, 437; Stony Mountain, 434; Millwood, 498; Swan River, 496. Common.

Pileolaria Toxicodendri (Berk. and Rav.) Arth., III on Rhus Toxicodendron, 77*J*.; Brandon, W. P. F.

Polythelis Pulsatillae (Rostr.) Arth., on Pulsatilla ludoviciana, Virden, coll. P. R. Cowan, det. W. P. F.

P. Thalictri (Chev.) Arth., III on Thalictrum venulosum, I. L. C., 1171*F*.

Puccinia abundans (Peck) Jackson, I on Symphoricarpos sp., 214, 79; Russell, 1004; Rapid City, I. L. C.

P. amphigena Dietel. Reported by W. P. F., I on Nemexia lasioneuron, Brandon; and II, III on Calamovilfa longifolia.

P. Andropogonis Schw. (P. pustulata Arth.), I on Comandra pallida, 81.

P. angustata Peck. Reported by W. P. F., I on Mentha canadensis, Brandon, Dauphin; and II, III on Scirpus microcarpus, Brandon. (See Mycol. XI, 130.)

P. Antirrhini Diet. and Holw., II on Antirrhinum majus (cult.), greenhouse, M. A. C. J. F. Higham, Mar. 1920 (first report for Manitoba). During 1920,

it became destructive in gardens around Winnipeg; 73, 131, 195. Probably occurred previous to 1920, but was not noted. Not found in 1921.

P. Asparagi DC., II, III on Asparagus officinalis, 270; Brandon, W. P. F. Not found to be serious.

P. Asperifolii (Pers.) Wettst., II on Secale cereale, I. L. C., 142; V. W. Jackson, 274; Swan River, 474. Common, but not serious on rye.

P. Asteris Duby, III on Aster Novae-Angliae, reported by W. P. F., Brandon.

P. Asterum (Schw.) Kern., I on Solidago rigida, S. spp., Aster spp., Grindelia squarrosa, 76, 295, 294, 211; Brandon, W. P. F.; Morris, I. L. C., 93; Virden, 291; Riding Mountains, 466; Swan River, 488; II, III on Carex scoparia, Brandon, W. P. F.

P. calthaecola Schr., I, II, III on Caltha palustris, Dauphin, W. P. F.

P. Cicutae Thuem., on Cicuta maculata, Brandon, W. P. F.

P. Cirsii Lasch, on Carduus Flodmani, Brandon, W. P. F.

P. Clematidis (DC.) Lagerh. (including P. Agropyri); I on Anemone canadensis, A. sp., 163; Morris, I. L. C., 196; Gilbert Plains, 1060; Lazare, 499; Swan River, 482; on Thalictrum dasycarpum, T. venulosum, 126, 71; Morris, I. L. C., 201, Eden, 454; Virden, 290; Swan River, 1076; on Actaea alba, A. rubra, 155*J*., 156, 293; Eden, 455. II, III on Bromus ciliatus, Neepawa, I. L. C., 105; Elymus virginicus, 267; E. Macounii, Morris, I. L. C., 210. Also collected by W. P. F. on Agropyron tenerum, A. Richardsonii, A. Smithii, Bromus latiglumis, Elymus canadensis, Hordeum jubatum, Poa arida. A very common rust in Manitoba. For cultures made by Prof. Fraser, see Mycol. xi, 133, 1919. Collections on Bromus are of the P. tomipara type.

P. Distichlidis Ellis and Ev., I on Steironema ciliata, Morris, I. L. C., 124; Brandon, W. P. F.; II, III on Spartina Michauxiana, Waskada, 100; Brandon, W. P. F.

P. Eatoniae Arth., I on Ranunculus abortivus, Riding Mountains near Kelwood, 464. Placed here with some uncertainty, but the distributed aecia suggest this rust.

P. Eléocharidis Arth., I on Eupatorium purpureum, Brandon, W. P. F.; II, III on Eleocharis sp., Brandon, W. P. F.

P. Ellisiana Thuem., I on Viola canadensis, V. sp., 122, 87; II, III on Andropogon furcatus, Brandon, W. P. F.

P. epiphylla (L.) Wettst., II on Poa pratensis, P. sp., V. W. Jackson, 249, 250.

P. graminis Pers. I on Berberis vulgaris, 202, 138, 252; Brandon, 282. II, III on Triticum aestivum, first found during 1920 on June 30th, at Winnipeg; during 1921, on June 27th, at Emerson; thenceforth northward and soon found everywhere. On Hordeum vulgare, 181, 206, 259; on Avena sativa, A. fatua, 145, 204, 258; V. W. Jackson, 273; on Phleum pratense, 161, 275; Swan River, 480; Gilbert Plains, 1067. The II stage evidently lives over winter on timothy, since the rust can be found on timothy before it appears on grains. On Agropyron repens, A. tenerum, A. caninum, A. Smithii, 153, 261, 213, 208, 260, 262; Lyleton, 97; on Hordeum jubatum, 192, 193, 154, 117; Lyleton, 96. On Elymus Macounii, E. canadensis, 160, 278, Morris, I. L. C., 70. On Dactylis glomerata, 263; on Alopecurus pratensis; The Pas, V. W. Jackson, 266; on Festuca elatior, 265. On Beckmannia erucaeformis, Roblin, W. Rae. Also on other hosts. This is by far the worst plant disease in Manitoba.

P. Grossulariae (Schum.) Lagerh. I on Grossularia spp. and Ribes americanum, R. spp., wild and cultivated, 132, 441, Matlock, 133; Morris, I. L. C., 200; Eden, 457; Virden, 286. II and III on Carex spp., Brandon, W. P. F.

P. Helianthi-mollis (Schw.) Jackson, I, II, III on Helianthus annuus (cult.), H. fascicularis, H. sp., 470, 92, 171, 165; Portage la Prairie, I. L. C., 101; Brandon, I. L. C., 177; Melita, 110; Waskada, 98; Russell, 1007; Dauphin, W. P. F.

P. hemisphaerica (Peck) Ell. and Ev., I, II, III on Lactuca pulchella, 86, 255, 256, 1082; Lazare, 1001; Gilbert Plains, 1064; Thunder Hill, Swan River, 483.

P. hieraciata (Schw.) Jackson (P. patruelis Arth.), I on Lactuca pulchella, Nabalus albus, 86; Morris, I. L. C., 95; Eden, 462; Brandon, W. P. F.; II, III on Carex spp., Brandon, W. P. F.

P. Impatientis (Schw.) Arth., 0, I on Impatiens biflora, 191; Swan River, 492, 1080; Dauphin, W. P. F. Cultured by Prof. Fraser to Hordeum jubatum (Mycol. xi, 131, 1919).

P. Lygodesmiae, Ell. and Ev., on Lygodesmia juncea, Brandon and Virden, W. P. F.

P. Magnusianum Koern., II, III on Phragmites Phragmites, Dauphin, W. P. F.

P. Majanthae (Schum.) Arth. and Holw., I on Vagnera stellata, Unifolium canadense, 80, 83, Brandon, W. P. F.; II, III on Phalaris arundinacea, Brandon, W. P. F.

P. marylandica Lindr., I on Sanicula marylandica, 306; Brandon, W. P. F.

P. Menthae Pers., II on Mentha glabrior, M. canadensis (?), Monarda fistulosa, M. mollis, Gilbert Plains, 1059; Swan River, 486; Brandon, Dauphin, W. P. F.; Waskada, 99; Grand Beach, 162.

P. monoica (Peck) Arth., I on Arabis sp., W. P. F.; II, III on Trisetum spicatum, The Pas, V. W. Jackson, 257.

P. montanensis Ellis, II, III on Agropyron Smithii, Elymus canadensis, Brandon, Dauphin, W. P. F.

P. Peckii (De Toni) Kellerm., I on Oenothera biennis, 88, 240; II, III on Carex Sartwelli, Brandon, W. P. F.

P. Polygoni-amphibii Pers., II, III on Polygonum Hartwrightii, P. Muhlenbergii, 143; Gilbert Plains, 1015, 1065; Swan River, 490.

P. Rhamni (Pers.) Wettst. (P. coronata Corda), I on Rhamnus alnifolia, R. cathartica, 136, 203; Morris, I. L. C., 78; Swan River, 484; Brandon, W. P. F.; II, III on Avena sativa, Calamagrostis canadensis, C. Langsdorfii, Beckmannia erucaeformis, Sclerochloa festucacea, Bromus sp., 204, 283; I. L. C., 106, 129; Swan River, 484; Brandon, W. P. F.; The Pas, V. W. Jackson, 281; Grand Beach, 209.

P. rubefaciens Johans.. on Galium boreale, Brandon, W. P. F.

P. rubella (Pers.) Arth., I on Rumex mexicanus, R. occidentalis, Dauphin, W. P. F.; II, III on Phragmites Phragmites, Dauphin, W. P. F. (See Mycol. xi, 130, 1919.)

P. Sherardiana Koern., on Malvastrum coccineum (not certain).

P. Sorghi Schw., II, III on Zea Mays, 467, 469. These are the first specimens known to be collected in Manitoba. The rust came to be very abundant in 1921.

P. Stipae Arth., II, III on Stipa comata, W. P. F.

P. substerilis Ellis and Ev., III on Stipa viridula, Rapid City, I. L. C., 113*F*.; Brandon, W. P. F.; common.

P. Taraxaci (Reb.) Plowr., III on Taraxacum officinale, 121, 190, 1085; Gilbert Plains, 1063.

P. triticina Eriks., II, III on Triticum aestivum, 207; Ste. Rose, 1014, 1069; Swan River, 473. Occurred wherever wheat was grown in Manitoba in 1921, and caused considerable loss.

P. universalis Arth., 0, I on Artemisia gnaphaloides, Brandon, W. P. F.; II, III on Carex praegracilis, Brandon, W. P. F.

P. Urticae (Schum.) Lagerh., I on Urtica Lyalli, U. gracilis(?), Morris, I. L. C., 94; Swan River, 1075; Dauphin, W. P. F.; II, III on Carex spp., Brandon, W. P. F.

P. Xanthii Schw., III on Ambrosia trifida, Morris, I. L. C., 104.

P. Ziziae Ell. and Ev., on Zizia aurea, Brandon, I. L. C., 1198.

Pucciniastrum arcticum (Lag.) Tranz., II, III on Rubus triflorus, W. P. F.; V. W. Jackson, G. R. B., 223*J*.

P. pustulatum (Pers.) Diet., II, III on Epilobium adenocaulon, Brandon, W. P. F.

P. Pyrolae (Pers.) Diet., on Pyrola rotundifolia, 364*D*, 84.

Uredinopsis Struthiopteridis Storm., II, III on Onoclea Struthiopteris, 74; I. L. C and G. R. B., 158*J*.; 468. Common.

Uromyces acuminatus Arth., 0, I on Smilacina stellata and II, III on Spartina michauxiana, Brandon, W. P. F.

U. Alopecuri Seym., I on Ranunculus Macounii, R. scleratus, Brandon,

W. P. F., and collected on and cultured to Alopecurus aristulatus (Mycol. XI, 129, 1919). Aecia considered to belong to this rust were collected in the Riding Mountains near Kelwood, 463.

U. Fabae (Pers.) de Bary, I, II, III on Lathyrus ochroleucus; Viola americana, 221; Swan River, 489, 478, 1078; Neepawa, I. L. C., 215; Gilbert Plains, 1019; Brandon, I. L. C., 184.

U. Glycyrrhizae (Rab.) P. Magn., on Glycyrrhiza lepidota, V. W. Jackson, 1137; Swan River, 1077; Morris, I. L. C., 217.

U. Junci (Desm.) Tul., II, III on Juncus balticus, Brandon and Oak Lake, W. P. F.

U. Polygoni (Pers.) Fcl., I, II on Polygonum aviculare, 85, 248.

U. porosus (Peck) Jackson, on Vicia americana, I. L. C., 1095.

U. proeminens (DC.) Pass., II, III on Euphorbia (Chamaesyce) sp., 242.

U. Trifolii (Hedw. f.) Lév., I, II, III on Trifolium repens; T. hybridum, 169, 168, 166, 245; Swan River, 479. Aecia are common and were collected as late as Aug. 24th, 1921, 1096.

Tremellales.

Exidia albida (Huds.) Bref. (?), Kenora.

E. glandulosa (Bull.) Fr., 362, 602; E. C. Stakman and A. H. R. B., 805; Kenora, 570.

Tremella clavarioides, 1162*Ll.*

T. mycetophylla Peck, on Collybia dryophila, coll. A. H. R. B.

Ulocolla foliacea (Pers.) Bref., on Abies balsamea, A. H. R. B.

Dacryomycetales.

Dacryomyces aurantia Schw., Kenora, 557*Ll.*

D. stillatus Fr. (?), 328.

Guepinia spathularia (Schw.) Fr., Kenora, 965.

Agaricales.

Thelephoraceae (including Hypochnaceae):

Aleurodiscus amorphus (Pers.) Rabenh., 20*V.*

A. cerussatus (Bres.) v. H. and L., 26*B.*, 65*B.* First record for North America.

Coniophora cerebella Pers., Kenora, 946*B.*

C. puteana Fr., Manitou, J. A. MacGregor, 1054*Ll.*

C. suffocata (Pck.) Massee, 925*B.*

Corticium arachnoideum Berk., 743*B*, Stony Mountain, 900*B.*

C. galactinum (Fr.) Burt, 1102*B.*

C. polygonium Fr., 394*B.*

C. roseum Pers., 936*B.*, Stony Mountain, 897*B.*

C. salicinum Fr., Shoal Lake, I. L. C., 429*B.*

C. vagum B. and C. Extremely abundant in the Rhizoctonia stage on potatoes throughout the agricultural areas of Manitoba, causing much damage. Also on other hosts, as sweet pea (Dauphin, 91).

C. vellereum E. and C., 720*B.*

Cyphella Tiliae (Peck) Cooke, 730*B.*

Eichleriella spinulosa (B. and C.) Burt, Swan River, 1048*B.*

Hymenochaete cinnamonea (Pers.) Bres., 31*V.*, 66, 731, 732*B.*, 944*B.*

H. Curtisii (Berk.) Marg., 736*B.*

H. rubiginosa (Dicks.) Lév., 748*B.* (resupinate).

H. tabacina (Sow.) Lév., 567*B.*

Hypochnus chalybaeus (Pers.) Bres., 1163*B.*

H. coriarius (Peck) Burt, coll. I. L. C. and G. R. B., 1215*W.*

H. fumosus Fr. (Corticium sulphureum Pers.), 1217*W.*

H. granulosus (Peck) Burt, 708*B.*

H. spongiosus Schw.?, 1158*B.*

Peniophora cinerea Bull., 10*V.*, 11*V.*, 25*V.*, 821, 878*B.*

P. crassa Burt (prob.), 26*xV.*

P. gigantea (Fr.) Burt, 28*V.*, 49*V.*
P. laevis (Fr.) Burt, 744*B.*
Stereum cinerascens Schw., 63*B.*, 740*B.*, 371, 945*B.*, 1118*B.*
S. fasciatum Schw., 746*B.*, 825*B.*
S. frustulosum (Pers.) Fr., 955*B.*, 956*B.*
S. fuscum (Schrad.) Quél. (S. bicolor Pers.), 741*B.*, 601*B.*, 1234*W.*, 827*B.*; Victoria Beach, 909*B.*; Shoal Lake, I. L. C., 427*B.*
S. gausapatum Fr., 34*V.*, 1235*W.*, 880*B.*, 1105*B.*, 721*B.*
S. purpureum Pers., 1231*W.*, 933*B.*, 938*B.*, 508*B.*, 722*B.*, 728*B.*, 826*B.*
S. rugum Fr., 24*V.*, 367, 500; Ethelbert, R. Pidruchney, 398; Swan River, 1028. Very common on fallen poplar branches.
S. versiforme B. and C. (Peniophora Ellisii Mass.), 1216*W.*
Thelephora laciniata Pers. (?), Minaki.

Clavariaceae: Calocera viscosa (Pers.) Fr., Kenora.
Clavaria abietina Fr., or C. flaccida Fr., 1160*Ll.*
C. cinerea Bull., 1159*Ll.*
C. formosa Fr., Victoria Beach.
C. pistillaris Fr., Kenora, 587, 797.
C. pyxidata Fr., Gimli, R. Hiebert, 628; Swan River, 1044; Russell; Gimli.
C. sp. (not in Cotton and Wakefield's paper), 1161*Ll.*
Typhula gyrans Fr., 1200*W.*

Hydnaceae: Grandinia spp., 44*V.*, 372*V.*, 879*B.*, 1182*B.*
Hydnum caryophylleum B. and C., 725*B.*
H. coralloides Scop., Gimli; Kenora, 538, 793.
H. ferrugineum Fr. (?), Minaki, 536.
H. imbricatum Fr., Minaki, 577.
H. Kauffmani Peck, 526*Ll.*
H. ochraceum Fr., 959*V.*
H. repandum Fr., Kenora, 563.
H. reticulatum (Banker) Sacc. and Trott (?).
Irpex ambiguus Peck (?), Winnipeg.
Mucronella minutissima Peck, coll. A. H. R. B.
Odontia fimbriata Pers., 726*B.*
O. fusco-atra Fr., Swan River, 1043*Ll.*
Phlebia cinnabarina Schw., 1177*B*
P. strigoso-zonata Schw., 58*V.*, 749*B.*, 877, 852, 1222*W.*; Minaki, 546.
Radulum spp., 1*V.*, 723*V.*
Tremellodon gelatinosum (Scop.) Fr., Kenora.

Polyporaceae: It will be observed that Dr Overholts has determined most of the species (those marked *V.*). The vicinity of Winnipeg has been fairly well surveyed for Polypores. The nomenclature used by Overholts has been followed and Polystictus is included under Polyporus.
Daedalea confragosa (Bolt.) Fr., 53*V.*, 784, 838*V.*; Kenora, 548.
D. unicolor Bull., 2*V.*, 598, 833, 839.
Favolus canadensis Klotz., 336, 555, 442, 1109; Kenora, 796; Swan River, 1031.
Fomes applanatus (Pers.) Wallr., 419; Shoal Lake, H. F. Roberts, 755*W.*; Russell, 1021*V.* and 1023*V.*
F. connatus Weinm. (F. populinus Fr. ?), 61*V.*, 752*V.*
F. fomentarius (L.) Gill., 841, 418, 951*V.*; Kenora, 700, 701*V.*; Shoal Lake, H. F. Roberts, 759. Common.
F. fulvus Scop. (?), 40*V.*
F. igniarius Fr. Common on living poplar, willow, ash, and other trees. Often reaches an age of 20 or 30 years or more. Quite destructive to trees. Tests showed that spore-fall in Manitoba occurs during July and August. Often resupinate, 15*V.*, 365, 953*V.*, 1114, 853; Kenora, 568, 703 and 705; Shoal Lake, H. F. Roberts, 758; Swan River, 1027.
F. pinicola Sw., 33*V.*, 845*V.*, 950*V.*; Gimli, R. Hiebert, 864; Swan River, 1039*V.*; Dr Overholts considers No. 845 to be a variation from the usual type.

F. (Trametes) scutellatus Schw., Kenora, 709*V.*
Lenzites abietina (Bull.) Fr. (? not certain that this species occurs in N. A., possibly L. saepiaria), 1045*V.*, 588.
L. betulina Fr., 603, 846; Kenora, 548*V.*; Minaki, 573; Gimli.
L. saepiaria Fr. (Trametes protracta Fr. when poroid), 41*V.*, 354, 750, C. W. Lowe, 586; Minaki, 572; Gimli.
L. trabeus (Pers.) Fr. (L. vialis Pk.), 50*V.*
Merulius ambiguus Berk., Shoal Lake, I. L. C., 428*B.*
M. corium Fr., 943*B.*
M. niveus Fr. (?), Kenora, 558*B.*
M. tremellosus (Schrad.) Fr., Kenora, 706*V.*, 542*B.*, Shoal Lake, H. F. Roberts, 829*B.*
Polyporus abietinus Fr., Swan River, 1046*V.*
P. adustus (Willd.) Fr., 5*V.*, 16*V.*, 17*V.*, 517, 834, 38*V.* Very common.
P. albiceps Pk.?, 1100*V.*
P. betulinus Bull., 3*V.*; Kenora, 702; Shoal Lake, H. F. Roberts, 757*W.*, Shoal Lake, I. L. C. (May 24, 1921; previous year's pileus producing spores), 1143*W.*
P. biformis Kl., 927*V.*
P. brumalis (Pers.) Fr., 45*V.*, Kenora, 449, 704; Minaki, 545.
P. chioneus Fr., 876, det. E. C. Stakman.
P. cinnabarinus (Jacq.) Fr., Victoria Beach, 810. Not common.
P. conchifer (Schw.) Fr., 844*B.*
P. cuticularis Bull., 957*V.*, Victoria Beach, 908*V.*
P. dichrous Fr., 13*V.*, 27*V.*, 856, 719*V.*, 1178*V.*; Stony Mountain, 893.
P. elegans (Bull.) Fr., 37*V.*, 824*W.*, 1110; Gilbert Plains, 1051; Swan River, 1034.
P. fumosus (Pers.) Fr. (P. fragrans Pk.), 59*V.*
P. hirsutus Fr., 68*V.*, 785, 875, det. E. C. Stakman, 907*V.*
P. lucidus Fr. (?), Kenora, 801.
P. pergamenus Fr. (including P. subchartaceus Murr.), 7*V.*, 9*V.*, 597, 754*V.*; Shoal Lake, H. F. Roberts, 760; Hillside Beach, 416; Ethelbert, W. N. Pidruchney, 399*V.*, Stony Mountain, 896*V.*; Swan River, 1030. Common.
P. peckianus Cooke (?), 961*V.*
P. perennis (L.) Fr., 823*W.*, 960*V.*; Kenora, 566*aV.*, 905*V.*
P. picipes Fr., 906*V*; Gimli, 904*V.*
P. planellus Murr., 27*xV.*, 1123*V.*, 1121*V.* Quite common in Sept. 1921 at Winnipeg.
P. pubescens Schum. (?), Russell, 1022*V.*
P. spumeus (Sow.) Hornem. (P. occidentalis Murr.?), 935*V.*
P. squamosus Pers., small form, 14*V.*
P. sulphureus (Bull.) Fr., 836. Not common.
P. tulipiferus (Schw.) Overh., 4*V.*, 36*V.*, 23*V.*, 30*V.*, 32*V.*, 818, 742, 952*V.*, 1180*V.*; Kenora, 569*V.*; Swan River, 1037*V.* Common and rather variable in appearance.
P. tuberaster Fr. Sclerotia of what is perhaps this fungus (probably the same as Grifola tuckahoe Güssow) are common in fields. See Lloyd, Myc. Note 833.
P. ursinus Lloyd, 753*V.* Not common.
P. velutinus Fr., 6*V.*, 8*V.*, 19*V.*, 751, 501*V.*; Stony Mountain, 894 and 928.
P. versicolor (L.) Fr., 35*V.*, 54*V.*, 831, 832, 840; Stony Mountain, 895*V.*
P. volvatus Peck. On spruce, Ethelbert, W. N. Pidruchney, 400*V.*; Swan River, 1026; Russell. Common northward in Manitoba.
Poria attenuata Peck, 43*V.*, 48*V.*
P. calcea Fr., Swan River, 1036*B.*
P. eupora Karst., 1212*W.*
P. ferruginosa Schrad., 51*V.*, 60*V.*
P. laminata Murr., 12*V.*
P. mutans tenuis Peck (?), 727*V.*
P. ornata Peck, or a similar species, 57*V.*

P. prunicola Murr., 46*V.*
P. Vaillantii Fr., 52*V.*
P. washingtonensis Murr. On deciduous wood, 21*V.*
Solenia anomala Pers., 554*B.*
S. fasciculata Pers. (det. G. F. Atkinson), Winnipeg, A. H. R. B.
Trametes carnea Nees, 39*V.*, 352, 855, 396*V.*, 747*V.*; Gilbert Plains, 1053; Swan River, 1040*V.*; Kenora, 552; Minaki, 543.
T. hispida (Bagl.) Fr., 745*V.*, 902*V.*, 448; Matlock, 348*V.*; Gimli, 903*V.*; Stony Mountain, 890; Gilbert Plains, 1052; Swan River, 1029. Common and variable.
T. rubescens Fr. (Poroid form of Daedalia confragosa (L. O. Overholts, 1120*V.*).)

BOLETACEAE: Boletinus pictus Peck, Kenora, 802.
Boletus flavus Wither., Kenora, Winnipeg.
B. scaber Fr., 717, 1119; seen at Swan River, Russell, Kenora. Common, and the only Boletus found in 1921.

AGARICACEAE: Although over a hundred gill fungi are here listed, very many more occur in Manitoba. Several of these are listed with question-marks, for it is difficult to get determinations of Agarics verified because they decay so rapidly. Dr Kauffman has determined a few. The nomenclature used by Kauffman is followed. The species are arranged by spore colour

Leucosporae: Amanita muscaria Fr., 323, 1122; Kenora, 710; Greenway, C. Vickers Jr., 1196. This poisonous mushroom was common in 1921 in August and September.
A. phalloides Fr., Kenora; no definite record known from Manitoba, but it probably occasionally occurs.
Amanitopsis vaginata Fr., Winnipeg, Victoria Beach, Kenora; common in July and August.
Armillaria mellea Fr., Winnipeg, Kenora.
Cantharellus aurantiacus Fr., Kenora, 556, 561.
C. cibarius Fr., Kenora.
C. umbonatus Fr., Minaki.
Clitocybe gigantea Fr., Gimli.
C. laccata Quél. (Laccaria Berkeley).
C. maxima Fr., Gimli, Minaki.
C. Trogii Sacc. (?), Kenora.
Collybia cirrhata Fr., Gimli, 814; Kenora, 848.
C. confluens Fr., F. J. Higham, 435.
C. dryophila Fr., 332, 447, 1124; Hillside Beach, 415.
C. racemosa Pers. (?), Minaki, 635.
C. tuberosa Fr., Kenora, 816, 847, 849; Gimli.
C. velutipes Fr., Apr. 3rd, 1921, 321; Gimli; Kenora.
Hygrophorus chrysodon Fr., Kenora, 857 and 560.
H. conicus Fr., Gimli.
H. niveus Fr., Gimli.
Lactarius deliciosus Fr. In a squirrel's nest, Treesbank, S. Criddle, 940*K.*, Gimli, Minaki. For other fungi collected by squirrels see also Buller, A. H. R., Trans. Brit. Myc. Soc. VI, 355, 1920.
L. glyciosmus Fr., Minaki.
L. piperatus Fr., Winnipeg, Gimli, commonly parasitized by Hypomyces.
L. rufus Fr., Minaki.
L. torminosus Fr., Gimli. Reported by some to be poisonous.
L. uvidus Fr. ("very probably" *K.*). Another fungus collected by squirrels, Treesbank, S. Criddle, 939*K.* Considered poisonous to man and guinea-pigs, but not to rabbits (Kauffman). Dr Kauffman reports certain other fungi sent him from squirrels' nests to be probably Lactarii.
Lentinus lepideus Fr., Ste. Rose, 1009; Deloraine; Selkirk. Everywhere on railway ties; also collected on living Negundo aceroides, I. L. C., 1055*K.*
Lenzites, see Polypores.
Lepiota naucina Fr., 1211.

Marasmius epiphyllus, Fr., 1181*K*.
M. oreades Fr., 843.
M. rotula Fr., 1144*K*.
M. siccus Schw.(?), Winnipeg.
M. urens Fr., det. E. C. Stakman. Reported by some to be poisonous.
Mycena alcalina Fr., Minaki, Kenora.
M. galericulata Fr., 1115; Kenora.
M. pura Fr., Kenora.
Omphalia campanella Fr., Kenora, 562, 716, 860.
O. campanella badipus, Kenora, 799.
O. epichysium Fr.(?), I. L. C., Winnipeg.
Panus rudis Fr., 854; Victoria Beach, 809.
P. stypticus Fr., 502.
Pleurotus circinatus Fr., Winnipeg.
P. ostreatus Fr., 335, 600; Swan River.
P. ulmarius Fr., 347, 585. Common on elms and maples around Winnipeg.
Russula aeruginea Lindbl., I. L. C., 1203.
R. aurantialutea Kauff., from a squirrel's abode, Minaki, Dr C. N. Bell, 931*K*.
R. emetica Fr., 1204; Swan River; Minaki
R. integra Fr., Minaki, Gimli.
R. nitida Fr (?), Gimli.
R. virescens Fr., Kenora.
Schizophyllum commune Fr., 506, 589, 777, 112, 355; E. C. Stakman and A. H. R. B., 804; Swan River, 1024. Very common everywhere.
Trogia crispa Fr., 619; Kenora, 712.
Rhodosporae: Claudopus nidulans Fr., 851; Gimli, 584.
Pluteus cervinus Fr., Winnipeg; Gimli; Kenora, 713.
Volvaria speciosa Fr., Mr Rigby, 337; Gimli.
Ochrosporae: Cortinarius armillatus Fr., Minaki, 571.
C. cinnamomeus Fr.(?), Kenora.
C. mucifluus Fr., Minaki, 541; Kenora, 714.
C. violaceus Fr.(?), Kenora.
Crepidotus herbarum Pk., Swan River, 1104*K*.
C. mollis, Fr., 443.
C. versutus Pk., Gimli.
Flammula sapinea Fr., Gimli.
Galera hypnorum Fr., Pointe du Bois.
G. tenera Fr., Gimli, 642.
Hebeloma sp., Russell.
Inocybe sp., Winnipeg.
Naucoria hamadryas Sacc., Hillside Beach, 414.
N. pediades Fr., 331.
N. semiorbicularis Fr., Winnipeg.
Paxillus involutus Fr.(?), Winnipeg.
P. panuoides Fr., on sawdust, Gimli.
Pholiota adiposa Fr.
P. dura Bolt. (?), St Charles.
P. erinaceella Pk., I. L. C., J. F. Higham, G. R. B., 1103*K*.
P. squarrosa Quél.(?), Gimli, 583. This species may be limited to Europe, according to Kauffman.
P. squarrosoides Pl.(?), Minaki, 576.
Porphrosporae: Hypholoma appendiculatum Fr., Winnipeg, Stony Mountain.
H. fasciculare Fr., Gimli.
H. incertum Pk. var. sylvestris Kauff., 1106.
H. perplexum Pk., Winnipeg.
Psalliota (Agaricus) campestris Fr., bisporous form, C. W. Lowe, 763.
P. campestris Fr., quadisporous form, Gimli.
P. sylvatica Quél. (?), Kenora, 549.
Stropharia epimyces (Pk.) Atk., 882. Det. E. C. Stakman; reported by Kauffman to have been seen by Pennington at Winnipeg.

S. semiglobata Fr., Gimli.
Melanosporae: Anellaria separata Karst., Gimli.
Coprinus atramentarius Fr., 634, 789, C. W. Lowe, 790, 1108.
C. comatus Fr., C. W. Lowe, 787, 792.
C. curtus Kalchbr. Common at Winnipeg.
C. domesticus Fr., Winnipeg.
C. ephemerus Fr., Winnipeg.
C. Hendersonii Berk. On horse-dung, Winnipeg.
C. lagopus Fr. (C. fimetarius Fr.), Winnipeg.
C. micaceus Fr., 330; common.
C. narcoticus Fr., Winnipeg.
C. niveus Fr., Winnipeg.
C. plicatilis Fr., 835.
C. stercorarius Fr., 815, 817, 887, 888.
C. sterquilinus Fr., R. Hiebert, 627.
Gomphidius glutinosus Fr., Kenora, 798.
G. viscidus Fr., Kenora 550; Minaki, 575.
Panaeolus campanulatus Fr., 440, 436; Hillside Beach, 413; Thunder Hill.
P. papilionaceus Fr., 1201.
P. solidipes Peck, Winnipeg, A. H. R. B.; Sturgeon Creek, C. W. Lowe, 791.
Psathyra persimplex Britz., 1209.
Psathyrella disseminata Fr., 424, 1107.
P. crenata (Lasch.) Fr.(?), 1205.

Phallales.

Dictyophora Ravenelii (B. and C.) Burt, Kenora, 613.

Lycoperdales.

Bovista plumbea Pers., 378*Ll.*; Gimli, 529*Ll.*; Kenora, 884.
Calvatia coelata (Bull.) Morg. (?), Gimli, 533.
C. gigantea (Batsch) Morg., 339; Gimli.
C. pachyderma (Peck) Morg. (?), Gimli, 535.
Geaster coronatus Schaeff., Kenora, 813*Ll.* Very similar to L. minimus.
H. hygrometricus Pers., Victoria Beach, 812*Ll.*
G. rufescens Schm., 599*Ll.*
Lycoperdon cepaeforme Bull., 811*Ll.*, Gimli, 531*Ll.*
L. gemmatum Batsch, 837*Ll.*
L. piriforme Schaeff., 921*Ll.*, 370*Ll.*; Matlock, 383; Eden, 450; Shoal Lake, H. F. Roberts, 828*Ll.*
L. polytrichum Lloyd, Point du Bois, 918*Ll.*
L. Wrightii Berk., Gimli, 530*Ll.*
Mycenastrum corium Desvaux, 379*Ll.*
Secotium acuminatum Mont., Gimli, 624; Sturgeon Creek, 625.
Sphaerobolus stellatus Tod., Kenora.
Nidulariales: Crucibulum vulgare Tul., Kenora, 929.
Cyathus striatus (Huds.) Hoffm., 596, 349; Kenora.
C. vernicosus (Bull.) DC., 338.
Nidularia pisiformis (Roth.) Finl., Kenora, 964.
Uncertain: Ptychogaster subiculoides, named by Lloyd from 1164 sent him. Quite common in 1921, but never developed into anything definite.

LICHENS.

The majority of the species listed for convenience here were collected by John Macoun, principally from Lake Winnipegosis and other points north of the agricultural area of Manitoba, and listed in his paper "Catalogue of Canadian Plants. Part VII. Lichens and Hepaticae." Geol. Survey of Can. 1902, pp. 49–180. Macoun lists 614 lichens for Canada, and Fink (Minn. Bot.

Stud. III, 167–236, 1903) records 310 from the northern boundary of Minnesota (most of which naturally occur also in Manitoba); it is obvious that this list covers but a small fraction of the forms which occur in Manitoba.

The letter "*M.*" after a record indicates that the species is listed by Macoun. Where the names he used differ from those used by Smith (A Monograph of the British Lichens, 1918 and 1911), the name in Macoun's list is included in parenthesis.

Alectoria jubata (L.) Ach. (Bryopogon jubata var. implexa, Fr.), Porcupine Mts., *M.*

Arthonia patellulata Nyl., on aspen poplar trees, Moose Mt., July 3rd, 1880, *M.*

A. radiata var. Swartziana (Ach.) Sydow (A. Swartziana Ach.), on balsam fir, Lake Winnipegosis, *M.*

Biatorella moriformis (Ach.) Th. Fr. (Biatora moriformis Ach.), on bark and dead wood, Lakes Manitoba and Winnipegosis, July 2nd, 1881, *M.* Reported in Macoun's list only from Manitoba.

Bilimbia sabuletorum B. and R. (Biatora hypnophila (Turn.) Tuckerm.), on moss along Lake Winnipegosis, *M.*

B. sphaeroides (Dicks.) Koerb. (Biatora sphaeroides (Dicks.) Tuckerm.), on moss at base of trees, Red Deer River, Porcupine Mts., *M.*

Cladonia alpestris (L.) Rabenh. (C. sylvatica var. alpestris L.), on Duck Mts., *M.* Fox Lake, Ont., 606.

C. coccifera (L.) Willd., coll. A. H. R. B.

C. crispata Flot. (C. furcata (Huds.) Fr. var. crispata Floerk.), on earth, Red Deer River, Porcupine Mts., *M.*

C. crystatella Tuck., 632; Fox Lake Ont., 605.

C. deformis (L.) Hoffm., on earth, Red Deer River, Porcupine Mts., *M.*

C. fimbriata var. simplex Wainio (var. tubaeformis Fr.), on rotten logs, Lake Winnipegosis, *M.*

C. fimbriata var. radiata Cromb., on the Porcupine Mts., *M.*

C. gracilis (L.) Willd. var. hybrida Schaer., at Lake Winnipegosis, *M.*

C. gracilis var. elongata Fr., on old logs, Red Deer River and Porcupine Mts., *M.* (Perhaps same as preceding.)

C. pyxidata (L.) Hoffm., Red Deer River and Lake Winnipegosis, *M.*, 633.

C. rangiferina (L.) Web., 762. The Reindeer Moss.

C. squamosa Hoffm., Lake Winnipeg (Herb. Hooker), *M.*

C. sylvatica (L.) Hoffm., in woods, Duck Mts., *M.*

C. turgida Hoffm. var. conspicua (Schaer.) Nyl., in woods, Duck Mts., *M.*

Collema tenax (Sw.) Sm., on earth, Otterbourne, *M.*

Evernia prunastri (L.) Ach., on trees, Duck Mts. and Lake Winnipegosis, *M.*

Graphis scripta Ach. var. limitata Schaer., on bark along Lake Winnipegosis, *M.*

Gyalecta lutea (Dicks.) Tuckerm., on spruce bark along Red Deer River, Porcupine Mts., *M.*

Gyrophora polyrrhiza (L.) Krb., Minaki, 626.

Lecanactis premnea Ach. var. chloroconia Tuckerm., on white spruce bark, Swan Lake House, Lake Winnipegosis, *M.*

Lecanora subfusca (L.) Ach. var. allophana Ach., on aspen poplar, Greenwood Twp. (Thos. Walker); on trees along Lake Winnipegosis, *M.*

Lecidea enteroleuca Fr. var. achrista Sommerf., on bark of trees along Lake Winnipegosis and on Moose Mts., *M.*

L. parasema Ach. (Buellia parasema Th. Fr.), on bark of paper birch, Red Deer River, Porcupine Mts., *M.*

L. vernalis (L.) Ach. (Biatora vernalis Fr.), on bark of trees, Red Deer River, Porcupine Mts., *M.*

Nephromium resupinatum D. T. and S. ("Nephroma tomentosum (Hoffm.) Koerb."), on trees, Manitoba House, *M.*

Parmelia caperata (L.) Ach., on dead wood, Manitoba House, *M.*
P. saxatilis (L.) Ach., on trees, Red Deer River; collected also by A. H. R. B.
P. sulcata Tayl., on rocks, Fox Lake, Ont., Dr F. C. Bell, 525.
P. tiliacea (Hoffm.) Ach., on rocks, Kenora, 807.
Peltigera aphthosa (L.) Willd., on earth in woods, Duck Mts., *M.*
P. canina (L.) Willd., coll. A. H. R. B.
P. rufescens (Neck.) Hoffm., on earth, Manitoba House, *M.*
Physcia hispida (Schreb.) Tuckerm., on poplar trees, Stony Mt., *M.*
P. orbicularis D. T. and S. (P. obscura (Ehrb.) Nyl.), on trees, Lake Winnipegosis, *M.*
P. stellaris (L.) Nyl., on trees at Winnipeg and Manitoba House, *M.*; C. W. Lowe, 770; common.
Placodium cerinum (Hedw.) Hepp., along Red Deer River, *M.*
Stereocaulon paschale (L.) Fr., on rocks, Kenora, Miss M. G. Rioch, 769; Fox Lake, Ont., 607.
Theloschistes chrysophthalmus (L.) Th. Fr., on trees, Lake Winnipegosis, *M.*
Usnea barbata Web. (U. barbata var. dasypoga Fr.), on trees in woods, Duck Mts., *M.*
U. florida Web. var. hirta Ach. (U. barbata var. hirta Fr.), Manitoba House and Porcupine Mts., *M.*
Xanthoria parietina (L.) Th. Fr. (Theloschistes parietinus Norm.), on stones, Lake Winnipegosis, *M.*; C. W. Lowe, 770.
X. polycarpa (Ehrb.) Oliv. (Theloschistes polycarpus Tuckerm.), on scrub oaks, Greenwood (Thos. Walker); on trunks, Red Deer River, Lake Winnipegosis, *M.*

REVIEW.

Fungi: Ascomycetes, Ustilaginales, Uredinales, by DAME HELEN GWYNNE-VAUGHAN, D.B.E., LL.D., D.Sc., F.L.S., Professor of Botany in the University of London. Demy 8vo, cloth, pp. xi + 232, with 196 figures in text. Price £1. 15*s.* net. Cambridge University Press.

It was long a reproach to mycologists in this country that there were few or no good English books on fungi. Students had to be referred to works in other languages or to translations of books which were often of relatively ancient date. The author has now removed this reproach, and all students of mycology will be grateful to her for this presentation of an eminently readable account of some of the most important groups of fungi. The book will be particularly welcome to university botanical students because it deals in a specially clear manner with the classification of the forms included in the Ascomycetes, Ustilaginales, and Uredinales. The book is written from the morphological standpoint with a strong cytological orientation, for although Chapter I deals with fungal saprophytism, parasitism, symbiosis, and with the reactions of fungi to stimuli, only the fringe of these interesting topics is touched upon. A clear idea of the morphology of the fungi, such as this book conveys, is essential to anyone who wishes to follow one of the many avenues of investigation now available in mycology, and it

would perhaps have made the book of undue length if some of these fascinating phases of the biology of the fungi had been explored in greater detail.

The author is a well-known worker on the cytology of the fungi, and her supreme interest in this aspect of mycology is evident throughout the book. She is an ardent believer in the existence of two nuclear fusions and two reduction processes in the life-cycle of the Ascomycetes, and is the founder of the term "brachymeiosis" to denote the third nuclear division in the ascus as described by her and others. Mention is made of the alternative view, that, like all other organisms of a sexual nature, the Ascomycetes possess only a single nuclear fusion and reduction process in their ontogeny. The author sums up this divergence of outlook as follows: "according to our present knowledge of the cytology of the Ascomycetes there are two nuclear fusions in the life-history of these plants," a statement which, in view of the large amount of recent work that points in the other direction, is somewhat surprising. However, as an account of the comparative morphology of the sexual organs of the Ascomycetes there is no book to approach it in excellence.

The chief innovation in the classification of the Ascomycetes is the institution of the group, Plectomycetes, to include the Plectascales (Endomycetaceae, Aspergillaceae, etc.), Erysiphales, and Exoascales. This is a very convenient arrangement, but its significance is uncertain, for, as the author emphasises, further investigation is required before much is known about the phylogenetic inter-relationships of the Ascomycetes. It is undoubtedly right to remove the Erysiphales from the Pyrenomycetes. In the general treatment of the Ascomycetes there are some notable omissions: for instance, there is no mention of such a common fungus as that causing apple canker.

Short chapters are devoted to the Ustilaginales and the Uredinales, but, apart from details of cytological development, the information is rather fragmentary. The occurrence of infection through the flowers in certain smut fungi of cereals is not mentioned, and there is only the barest reference to *Hemileia*, the most important rust genus in the tropics.

The letterpress and illustrations of the book are excellent. The wealth of figures is amazing, and they are beautifully executed, largely by the author herself. It is a special pleasure to see a reproduction of *Cyttaria Gunnii* from Berkeley. Unfortunately the price of the book is high (35s.), but it is indispensable to all serious students of fungi.

F. T. B.

PROCEEDINGS, 1922.

MEETING. UNIVERSITY COLLEGE, LONDON. *21st January.*

Dr W. Brown. On the Germination and Growth of Fungi at Various Temperatures and at Various Atmospheres.

Miss D. M. Cayley. Die-back of Stone Fruits due to *Diaporthe perniciosa* and the Behaviour of Monospore Cultures in Artificial Media.

Mr W. B. Crow. The Morphology and Affinities of *Leuconostoc mesenteroides*.

Mr W. J. Dowson. Michaelmas Daisy Wilt.

Dr M. C. Rayner. Obligate Symbiosis in *Calluna*.

MEETING. BOTANY SCHOOL, CAMBRIDGE. *18th March.*

Mrs M. N. Kidd. Diseases of Apples in storage.

Mr J. Line, M.A. The parasitism of *Nectria cinnabarina*.

Mr M. Mehta, M.Sc. Observations on the occurrence of wheat rusts near Cambridge.

Mr F. T. Brooks, M.A. and Mr C. G. Hansford, B.A. Mould growths on cold-store meat.